Attorney's Docket No. 1958.2 **PATENT**
Confirmation No. 6747

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: William Frederick Dew Jr.
Serial No.: 10/661,349
Filed: September 12, 2003
For: *HIGH RATE FILTRATION SYSTEM*

Group Art Unit: 1724
Examiner: Matthew O. Savage

Commissioner for Patents
Alexandria, VA 22313-1450

July 31, 2007

DECLARATION OF WILLIAM F. FOREMAN, III, P.E., UNDER RULE 132

I, William F. Foreman, III, P.E., make the following declaration:

1. I am giving this Declaration under 37 CFR Section 1.132 in connection with an Office Action mailed June 19, 2007 rejecting the pending claims of United States Patent Application Serial No. 10/661,349 filed September 12, 2003 (the "'349 application"). The pending claims are rejected based on a single document dated September, 1996 and authored by Onder Caliskaner and George Tchobanoglous, which is entitled *Evaluation of the Fuzzy Filter for the Filtration of Secondary Effluent* and was published by the Department of Civil and Environmental Engineering at the University of California in Davis (the "Caliskaner paper"). The Caliskaner paper is attached to this Declaration as Exhibit 1. No representation is made or intended that the date of September, 1996 is the actual date of publication of the Caliskaner paper.

2. I am providing this Declaration on behalf of Schreiber Corporation ("Schreiber"), the assignee of the '349 application by assignment from the sole named inventor, William Frederick Dew, Jr, to demonstrate that the Caliskaner paper is a publication of the applicant's own invention.

3. I was employed by Schreiber Corporation from 1988 until February 1999 and was Mr. Dew's immediate supervisor. I was employed as Schreiber's President from September 1996 to February 1999, which period includes the filing date of the first filed provisional patent application from which the above-captioned '349 application claims priority, which is provisional patent application Serial No. 60/032,643, filed on December 10, 1996 and attached hereto as Exhibit 2.

4. Prior to being employed as Schreiber's President, I was employed by Schreiber as its Director of Engineering and then Vice President of Operations and Engineering. I presently

am employed part-time by Schreiber LLC, which is a successor corporation to Schreiber Corporation, in the capacity of Consultant for matters related to intellectual property, and have served in this capacity since March 1999. I am also presently employed as Principal Investigator for The Resource Group in Birmingham, Alabama, a consulting company which I own and established in March 1999.

5. My educational background is as follows: I received B.S. and M.S. degrees in Mechanical Engineering from Auburn University in Auburn, Alabama. I also received a Master of Arts degree in Public and Private Management from Birmingham-Southern College in Birmingham, Alabama. I am a Registered Professional Engineer in two states, the State of Alabama (License No. 17057), and the State of Texas (License No. 56940). I have had approximately eighteen years experience in the field of waste water treatment. I published an article in the March 2006 issue of *Public Works Magazine* entitled "Down to a Science – Total Nitrogen Removal Simplified" on the subject of waste water treatment.

6. I am the author of a report entitled *Evaluation of the Filtration Bed Compression Gradient of the Fuzzy Filter; A Compressible Media Filter* (The Resource Group, 2002), which report was previously made of record in this '349 application as an attachment Exhibit B in support of the *Declaration of George Tchobanoglous, Ph.D. Under Rule 132* (the *Tchobanoglous* Declaration). This is the same George Tchobanoglous named on the Caliskaner paper. "Fuzzy Filter" is Schreiber's trademark Registration No. 2,162,319 for the subject matter described in the '349 application.

7. I am familiar with the Caliskaner paper attached to this Declaration as Exhibit 1. I am familiar with the Office Action mailed June 19, 2007, which is the most recent Office Action in the '349 patent application. I am familiar with the '349 patent application, its parent applications, including the provisional application attached as Exhibit 2, and their prosecution histories, and the development of the invention described therein and recited in the claims. I am familiar with the prior art documents previously cited in the prosecution histories. I previously submitted a *Declaration of William F. Foreman, III, P.E. Under Rules 56 and 132* dated August 30, 2006 in the '349 application.

8. Mr. Dew was employed by Schreiber from February 1, 1989 to December 31, 2002 in the capacity of Research & Development Engineer. While employed by Schrieber, I personally supervised Mr. Dew's activities and development of the invention recited in the pending claims of the '349 application. Mr. Dew's employment records show that he was born on June 15, 1928 and is at the time of this Declaration 79 years old.

9. Schreiber constructed a filtration apparatus according to Mr. Dew's invention and provided this apparatus in confidence to University of California at Davis for assessment by Dr. George Tchobanoglous as Principal Investigator of the performance of the filter with respect to statutory wastewater reclamation standards in California, Title 22. Dr. Tchobanoglous is a

recognized expert in the field of waste water filtration as shown in his Declaration, which is previously of record in the '349 application.

10. A final project report on the performance of the Schreiber filter of Mr. Dew's invention was provided to Schreiber as the Caliskaner paper, attached hereto as Exhibit 1. I am listed on page 1-2 of the Caliskaner paper as one of the individuals, along with several other Schreiber employees, without whose cooperation and assistance completion of the investigation would not have been possible. Mr. Dew is not listed since he did not interact directly with Dr. Tchobanoglous or Onder Caliskaner.

11. Schreiber received the Caliskaner paper in the Fall of 1996 and incorporated portions of the paper in the provisional application attached as Exhibit 2 in support of Mr. Dew's invention.

12. As recited at page 1-1 of the Caliskaner paper, "The purpose of this present study was to assess the performance of a new type of filter employing a compressible plastic filter medium. The filter known as the Fuzzy Filter was provided by the Schreiber Corporation. . . . The principal objective of the filtration studies is to evaluate the performance of the Fuzzy Filter . . . . with specific reference to Title 22 wastewater reclamation applications, ... The study described in this report involved the filtration of secondary effluent from the University of California at Davis (U.C. Davis) campus activated sludge treatment plant using a Fuzzy Filter provided by the Schreiber Corporation.

13. As can be seen from paragraph 12 above, the Caliskaner paper contains explicit and unqualified representations that the Fuzzy Filter filtration apparatus described in the provisional application attached hereto as Exhibit 2, and from which the '349 patent application claims priority, was received from Schreiber Corporation for the purpose of evaluation with respect to statutory wastewater reclamation standards.

14. In view of the representations contained in the Caliskaner paper it is evident the apparatus described in the '349 patent application was provided to the authors of the Caliskaner paper by Schreiber for evaluation and that the Caliskaner paper is a publication of applicant's own invention. It is respectfully submitted that the Caliskaner paper should not be a reference against the patentability of the claims as amended and is not prior art to these claims.

15. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; further, that these statements were made with the knowledge that willful false statements or the like so made are punishable by fine or imprisonment, or both, under 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application for any patent issued thereon.

July 31, 2007
Date

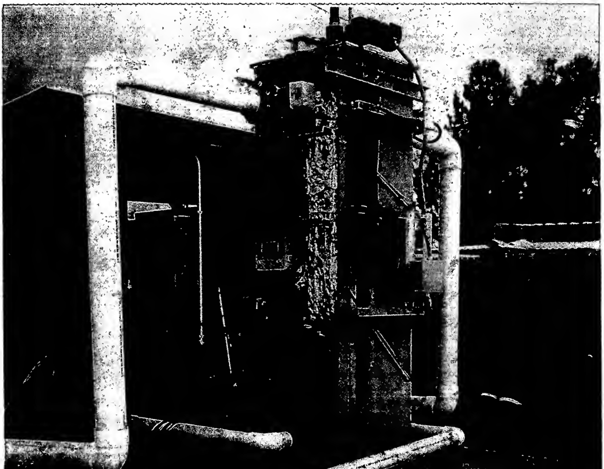
By: William F. Foreman III, P.E.
William F. Foreman, III, P.E.

Evaluation of the Fuzzy Filter for the Filtration of Secondary Effluent

Exhibit 1

Submitted August 3, 2007

EVALUATION OF THE FUZZY FILTER FOR THE FILTRATION OF SECONDARY EFFLUENT



Department of Civil and Environmental Engineering
University of California, Davis
September, 1996

By
Onder Caliskaner
George Tchobanoglous

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1
INTRODUCTION

As the discharge requirements for treated secondary effluent become more restrictive, effluent filtration is becoming a more integral part of secondary treatment. Because a high quality effluent is produced after filtration the potential for reusing treated effluent is being examined by a number of municipalities, especially those in the water short areas of the southwestern United States. In addition, a number of municipalities are interested in wastewater reclamation as a means of augmenting their sources of water. In California, before treated wastewater can be reused, certain water quality criteria, set by the California Department of Health Services (DOHS), must be met. Because of the stringent nature of the criteria, effluent filtration has become a critical feature in the implementation of the reclamation criteria.

PURPOSE

In previous studies conducted by wastewater agencies, consulting engineers, and at the University of California at Davis, a number of different types of filters have been evaluated for wastewater reclamation applications in California. The purpose of this present study was to assess the performance of a new type of filter employing a compressible plastic filter medium. The filter known as the Fuzzy Filter was provided by the Schreiber Corporation.

OBJECTIVES OF FILTRATION STUDIES

The principal objective of the filtration studies is to evaluate the performance of the Fuzzy Filter in wastewater filtration applications. Subobjectives include: (1) the quantification of the operating characteristics of the filter with specific reference to Title 22 wastewater reclamation applications, (2) evaluation of filter reliability and performance as affected by variations in effluent quality, and (3) evaluation of the backwash water requirements.

SCOPE

The study described in this report involved the filtration of secondary effluent from the University of California at Davis (U.C. Davis) campus activated sludge treatment plant using a Fuzzy Filter provided by the Schreiber Corporation. The

performance of the Fuzzy Filter was evaluated at four different filtration rates using various bed configurations in which the degree of bed compression is varied. Effluent quality was the criterion used to assess filter performance at various hydraulic loading rates. The filtration study discussed in this report was conducted at the University of California at Davis from April 1995 through September 1996.

ACKNOWLEDGMENTS

The completion of this investigation would not have been possible without the cooperation and assistance of numerous individuals. The authors are indebted Messrs. Peter Worthen, Adrian Carolan, Bill Foreman, and Larry Johnson of the Schreiber Corporation; the operating personnel of the U.C. Davis Campus Wastewater Treatment plant; and the staff of the Department of Civil and Environmental Engineering.

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BACKGROUND

Recognizing the importance of filtration in wastewater management, the purpose of this chapter is (1) to review briefly the Title 22 water reuse criteria, (2) to consider the impact of filtration on disinfection, (3) to review some previous effluent filtration studies, (4) to review of existing filtration technologies, and (5) to introduce a new innovative filtration technology.

WASTEWATER REUSE REQUIREMENTS

Health effects are of primary concern in the reuse and disposal of municipal wastewater. Disinfection by chlorination and or UV irradiation is common when treated wastewater is discharged to inland surface waters. While routine disinfection achieves essentially complete destruction of pathogenic bacteria and substantial deactivation of viruses, it does not provide complete virus destruction. Because viruses have been detected in disinfected secondary effluents, concern exists over protecting the health of individuals who may come in contact with the treated wastewater in reuse applications. As a result of this concern, the California Department of Health Services (DOHS) has established quality and treatment criteria for wastewater reuse in which human contact may occur. The wastewater reuse criteria, along with criteria for other reuse applications, are set forth in Title 22, Division 4, Chapter 3 of the California Administrative Code (hereafter referred to as Title 22).

Viral monitoring is not specified in Title 22, because, (1) viruses usually occur in low concentrations in treated wastewater, (2) their assay requires special expertise, (3) there is a long time delay in obtaining the results because of the involved laboratory procedures, and (4) the analytical costs are high. Instead of imposing measurements of viral concentrations, a tertiary treatment system consisting of chemical coagulation, sedimentation, filtration, and disinfection is specified in the Title 22 criteria where the public may be exposed to the treated wastewater, such as in recreational impoundments. After final filtration, turbidity of the treated effluent cannot exceed an average operating value of 2 NTU turbidity units and cannot exceed 5 turbidity units more than 5 percent of the time during any 24-hour period. The rationale for prescribing the above treatment

scheme and effluent criteria is that chlorination after this level of treatment should ensure effective virus destruction for the protection of public health. Direct filtration with chemical addition has been allowed as an alternative to the complete treatment system specified in Title 22, where it has been demonstrated that the results of the two treatment systems are comparable and meet the appropriate criteria.

IMPACT OF FILTRATION ON DISINFECTION

In recent studies dealing with the disinfection of filtered effluent it has been found that for a given chlorine or UV dose, the disinfection rates correlated well with the wastewater particle size distributions. Analysis of the data supports the conclusion that the ability to inactivate an individual wastewater particles containing bacteria is a function of the size of the particle. As a result, granular medium filtration is now almost universally required as part of the wastewater reclamation process.

In addition to improving the aesthetic quality of the reclaimed water and removing chlorine-demanding substances, direct tertiary filtration alone does not enhance the rate of disinfection unless the particle size distribution of the settled wastewater is modified. If a tertiary filtration system can operate to remove larger size particles completely, it should be possible to safely reduce the long contact times and high chlorine dosages typically employed in wastewater reclamation processes. Similar effects have been observed in the application of UV irradiation for the disinfection of filtered effluent.

PREVIOUS TITLE 22 DIRECT FILTRATION STUDIES

The treatment scheme prescribed in the Title 22 criteria (chemical coagulation, flocculation, filtration, and disinfection) has a very high capital and operational cost. Studies at the County Sanitation Districts of Los Angeles (CSDLAC, 1977), at the Tapia Water Reclamation Facility operated by the Las Virgines Municipal Water District (J. M. Montgomery Consulting Engineers, Inc., 1979), and at the University of California at Davis (Matsumoto and Tchobanoglous, 1981; Lang et al., 1986; and Weinschrott and Tchobanoglous, 1986) have been conducted to evaluate lower cost alternative treatment schemes involving the direct filtration of secondary effluent. A brief description of these studies is presented below.

Pomona Virus Study

The County Sanitation Districts of Los Angeles County conducted the Pomona Virus Study (CSDLAC, 1977) to evaluate less costly altematives to the complete Title 22 treatment scheme. A treatment scheme involving: (1) the addition of 5 mg/L alum and 0.06 mg/L anionic polymer, (2) direct dual-medium filtration at 200 L/m^2•min (5 gal/ft^2•min), and (3) two hours of chlorine contact time with a 10 mg/L combined chlorine residual performed equivalently to the complete Tittle 22 treatment scheme. Based on these results, the DOHS has allowed the use of dual-medium filters in direct filtration with coagulant addition.

Tapia Reclamation Study

In a 1979 filtration study conducted at the Tapia Reclamation Facility (J. M. Montgomery Consulting Engineers, Inc., 1979), it was demonstrated that a mono-medium filter was capable of producing an effluent of slightly better quality than that of the dual-medium filters used in the Pomona study. No virus testing was performed in this study. Based on the results obtained, the DOHS has allowed the use of the mono-medium filters in direct filtration with coagulant addition applications.

U.C.Davis Studies

Three types of filters have been tested at the U.C. Davis wastewater treatment facility: (1) pulsed-bed filter (Matsumoto and Tchobanoglous, 1981), (2) traveling bridge filter (Lang et al., 1986), and (3) upflow filter (Weinschrott and Tchobanoglous, 1986). All of the filters were operated in parallel with the DOHS approved dual-medium and deep-bed filters. All of the above filters were found to be capable of meeting the Title 22 requirements when used in the direct filtration mode without and with polymer addition. Based on the results of these studies, the DOHS has allowed the use of these three filters for direct filtration Title 22 applications.

EXISTING FILTRATION TECHNOLOGIES

Over the past ten years, a variety of filtration technologies have been developed and applied to the filtration of secondary effluent. The principal types of filter technologies are reviewed in the following discussion.

Types Of Filter Technologies

The principal types of filtration technologies include: (1) conventional mono-, dual-, and multi-medium downward flow filters, (2) deep-bed downward flow and/or upflow mono-medium filters, (3) pulsed-bed mono-medium downward flow filter, (4) shallow-depth single and dual-medium downward flow traveling bridge filters, and (5) continuous backwash upflow unstratified mono-medium deep bed filters. A new filter technology that has been developed recently is described below.

Comparison Of Alternative Types Of Filters

Based on parallel testing of five different types of filters for the direct filtration of secondary effluent at U.C. Davis it has been found that:

1. Given a high quality filter influent (turbidity less than approximately 7 to 10 NTU), all of the filters tested produced an effluent with an average turbidity of 2 NTU or less (see Fig. 2-1).
2. With a high quality influent (turbidity below 7 NTU), the average effluent quality from the various filters was indistinguishable.
3. When the influent turbidity was greater than about 7 to 10 NTU, chemical addition was required with all of the filters tested to produce an effluent with an average turbidity of 2 NTU or less.
4. Based on the results of the filtration studies, the conduct of additional side-by-side comparative filtration studies with dual-medium and deep-bed filters where turbidity removal is used as the performance criterion, is of limited value.
5. Using a low polymer dosage, it was possible, with all of the filters tested, to produce an effluent with an average turbidity of less than 2.0 NTU consistently and reliably with influent turbidities varying from about 3 to more than 30 NTU at a filtration rate of 200 $L/m^2 \cdot min$ (5 $gal/ft^2 \cdot min$).
6. Two major control strategies can be used to meet the Title 22 effluent quality requirements. In the first, the effluent quality is never allowed to go above a value of 2 NTU. In the second, the average effluent quality is maintained at 2 NTU or less.

NEW INNOVATIVE FILTRATION TECHNOLOGY

A new innovative filter involving the use of a synthetic fiber filter medium is currently being tested for Title 22 reclamation applications at the University of

California at Davis (see Figs. 3-3 and 3-4 in Chap. 3). The filter is unusual in a number of ways : (1) the synthetic filtering medium is highly porous, (2) the porosity (void ratio) of the medium can be modified, (3) to backwash the filter, the porosity (size) of the filter bed is increased mechanically, and (4) the filter operates at very high filtration rates [e.g., 400 to as high as 1600 L/m^2•min (10 to 40 gal/ft^2•min)]. The filter medium also represents a departure from conventional filter mediums in that the fluid to be filtered flows through the medium as opposed to flowing around the filtering medium, as in sand and anthracite filters. The operation of the filter is discussed in the following chapter.

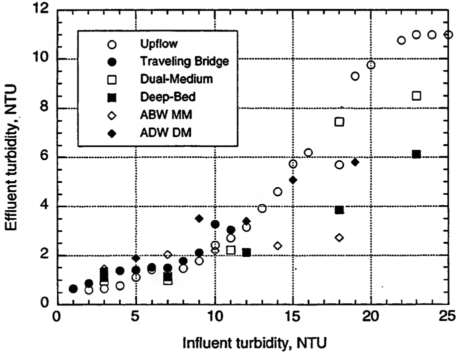

Figure 2-1
Comparison of effluent versus influent turbidity for various filters operated at 5 gal/ft^2•min

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FILTRATION EQUIPMENT AND APPURTENANCES

The test filter and the associated equipment were located at the U.C. Davis campus wastewater treatment plant. The layout of the U.C. Davis wastewater treatment plant is shown in Fig. 3-1. The treatment plant is a conventional complete-mix activated sludge process that receives wastewater generated on campus. Effluent from the secondary clarifier number 1 was drawn and used as influent for this study. The Fuzzy Filter, provided by the Schreiber Corporation of Birmingham, AL, was used to carry out the study. The principal components of the filter test facility, described in this chapter, include: (1) the influent feed system, (2) the test filter, and (3) the filter appurtenances.

INFLUENT AND EFFLUENT PIPING SYSTEM

A flow diagram for the filtration system test setup is shown in Fig. 3-2. The influent and effluent piping systems are described below.

Influent Piping System

As shown in Fig. 3-2, secondary effluent from secondary clarifier number 1 of the campus wastewater treatment plant was used as the influent to the Fuzzy Filter. Two centrifugal pumps, 3.75 kW (5 hp) and 2.25 kW (3 hp), are used to deliver the treated wastewater from the secondary clarifier of the wastewater treatment plant to the Fuzzy Filter. Each of the two intake manifolds is located approximately 300 mm (12 in) below the water surface just inside the effluent weir. Each manifold is made up of a 63-mm (2.5-in) diameter PVC pipe, 3.0 m (10 ft) long with 30-16 mm (5/8 in) circular inlets located at the midpoint of the pipe. The manifolds are attached to gate valves, which are used to control the pumping rate. Influent wastewater is then delivered by a 75-mm (3-in) PVC pipe, which is connected with a tee to a bypass loop located infront of the filter.

The bypass loop is equipped with a ball valve at the right side of the loop, which is used to regulate the backwash rate, and a gate valve followed by an automatic ball valve on the left side of the loop. The gate valve is used to regulate the filtration rate, and the automatic ball valve is used to divert flow to the right side

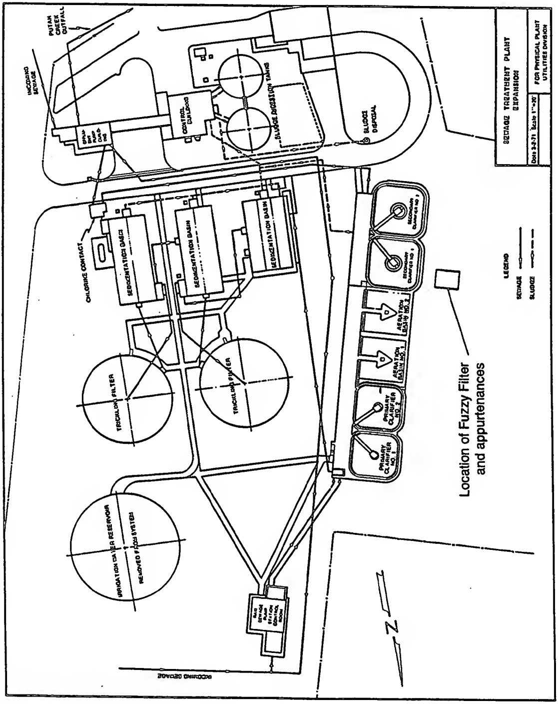

Figure 3-1
Layout of the University of California at Davis campus wastewater treatment facilities. Effluent from secondary clarifier number 1 of the activated sludge treatment plant was used as the influent for the Fuzzy Filter.

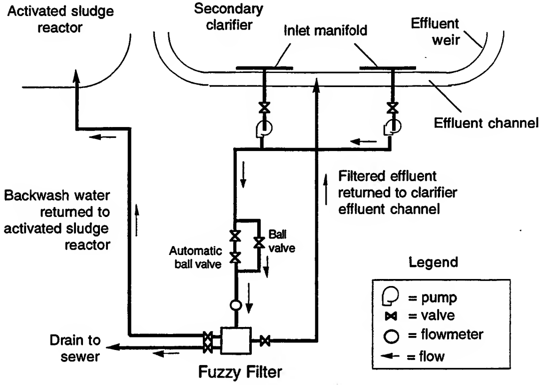

Figure 3-2
Flow diagram for the Fuzzy Filter test program

of the bypass loop, where the backwash rate is adjusted, as soon as the backwash cycle starts. A magnetic flow meter is located in the influent line following the bypass loop. A 6.5 mm (0.25 in) copper tube, is mounted at the side of the influent pipe to collect samples for the influent turbidity readings.

Effluent Piping System

The outlet piping from the filter consists of two 150 mm (6 in) PVC pipelines, and one 100 mm (4 in) (see Fig. 3-2). Filtered effluent from the filter is delivered back to the effluent channel of the secondary clarifier by the pipeline at the right side of the filter. Backwash water is returned to the activated sludge tank with the pipeline located at the left side of the filter. The 100 mm (4 in) line at the bottom of the filter is used to drain the filter, if required.

THE EXPERIMENTAL FILTER

In the Fuzzy Filter, shown in Fig. 3-3, a synthetic fiber porous material is used as the filter medium, instead of a conventional granular material. This filter has been designated the "Fuzzy Filter" by Schreiber Corporation, the manufacturer of the patented filtration process, because of the appearance of the filter medium. A description of the filter and its operation, the characteristics of the filter medium, and the air delivery system for filter backwashing are discussed below.

Description of the Filter Operation

A schematic of the filter is shown in Fig. 3-4. Because of its low density, the filter medium is retained between two perforated plates. Because the filter medium is compressible, the porosity of the filter bed can be altered according to the characteristics of the influent, by adjusting the position of the upper movable plate. The filter medium also represents a departure from conventional filter mediums in that the fluid to be filtered flows through the medium as opposed to flowing around the filtering medium, as in sand and anthracite filters.

During the filtration cycle, secondary effluent is introduced in the bottom of the filter into a plenum. The inlet plenum assures uniform distribution of the flow. The influent wastewater flows upward through the filter medium, and is discharged from the top of the filter. The filtration cycle is interrupted for backwashing, when the head loss through the filter medium reaches a preset maximum allowable level (i.e., terminal head loss), or the effluent quality deteriorates to an unacceptable level, usually referred as "breakthrough".

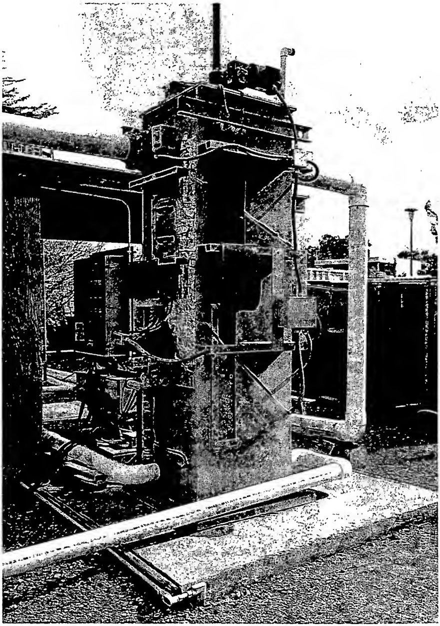

Figure 3-3
View of the Fuzzy Filter located at the UC Davis campus wastewater treatment plant

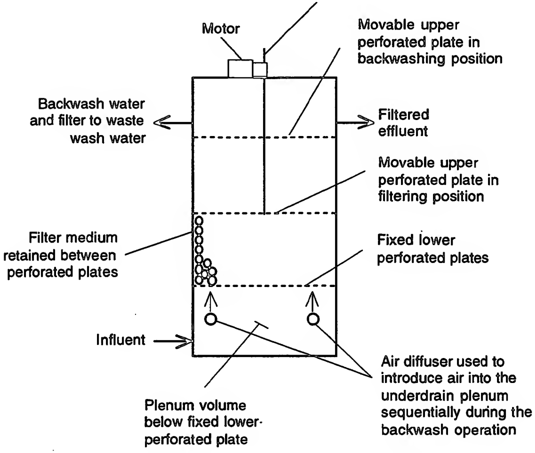

Figure 3-4
Schematic diagram of the operation of the Fuzzy Filter

At the inception of the backwash cycle, the flow is diverted to the backwash water line (see Fig 3-4) and the upper plate is moved up mechanically to increase the bed volume for backwashing. The backwash water is returned to the activated sludge process. While the secondary effluent flow continues to flow up through the filter, air is introduced below the lower perforated plate sequentially first from the left side and then the right side of the filter. The air creates turbulence and shear forces as it moves up through the expanded filter bed, which help to remove the accumulated material from the medium. The complete backwash cycle takes approximately 30 minutes. To start the next filtration cycle, upper perforated plate is returned to its original position, and the filter is flushed to waste for 1 minute to eliminate the discharge of any residual backwash solids with filtered effluent. Filter is put back into the filtration cycle upon the diversion of the flow from the backwash line to the effluent line. Summary information on the Fuzzy Filter used in this study is presented in Table 3-1.

Characteristics of the Filter Medium

The synthetic filter medium has a quasi spherical shape, and is approximately 30 mm (1.25 in) in diameter (see Fig. 3-5). The medium has some unusual properties; the medium is highly porous, and compressible. These two uncommon properties are unique and offer significant advantages over existing filtration technologies employing a solid medium. Based on displacement tests, the porosity of the filter medium itself is estimated to be about 88-90 percent. The porosity of the uncompacted filter bed is about 92 to 94 percent. The density of the medium is slightly greater than that of water. Experimental studies are underway to estimate the effective collector size of the medium. Porosity and collector size of the medium are two important parameters that effect effluent water quality, along with the development of the head loss across the filter medium. Because the filter medium is compressible, the porosity and the collector size of the medium can be altered according to the characteristics of the influent in various applications. It is also possible to alter the porosity and the collector size of the medium during the filtration cycle, to overcome the effect of the variations in daily influent water quality on the effluent quality.

Table 3-1
Summary information on the Fuzzy Filter test unit

Item	Unit	Value
Filter Characteristics		
Overall outside		
Length	m (ft)	0.85 (2.75)
Width	m (ft)	0.74 (2.4)
Height	m (ft)	3 (9.85)
Filtration area		
Length	m (ft)	0.7 (2.3)
Width	m (ft)	0.7 (2.3)
Area	m^2 (ft^2)	0.49 (5.25)
Piping		
Inlet	mm (in)	100 (4)
Filtered water outlet	mm (in)	150 (6)
Backwash water outlet	mm (in)	150 (6)
Filter drain	mm (in)	100 (4)
Filter Operation		
Nominal flow rates	L/min (gal/min)	100-795 (26-210)
Nominal filtration rates	$L/m^2 \cdot min$	205-1230
	($gal/ft^2 \cdot min$)	(5-30)
Maximum terminal headloss	mm (in)	2,540 (100)
Nominal backwash rate	$L/m^2 \cdot min$	410
	($gal/ft^2 \cdot min$)	(10)

Air Delivery System for Filter Backwashing

Air is supplied to the filter during the backwash cycle with a 5.6 kW (7.5 hp) Rotron centrigugal blower (see Fig. 3-6). Air is delivered to the filter through a 50 mm (2 in) stainless steel pipe, and introduced sequentially from the left and right sides of the filter below the lower perforated plate. The air flow is sequenced by means of two electormechanical valves located on the two air lines leading to the filter.

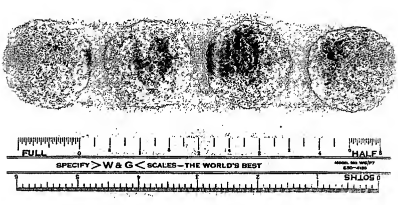

Figure 3-5
Fuzzy Filter filtering medium

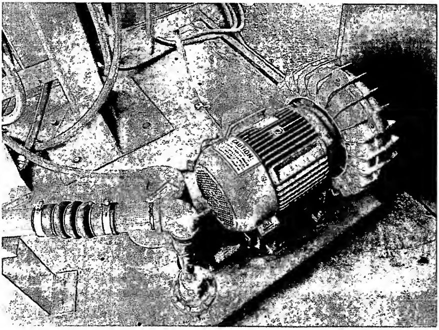

Figure 3-6
Air compressor used to provide air for the backwashing operation

FILTER APPURTENANCES

The principal fiter appurtenances include the (1) turbidity monitoring equipment and (2) head loss monitoring equipment.

Turbidity Monitoring Equipment

Two Hach 1720 C low range, continuous flow type nephelometric turbidimeters are used for turbidity monitoring. The turbidimeter consists of a control unit, head assembly, and turbidimeter body (see Fig. 3-7). All the electronics are contained in the control unit and head assembly. The control unit enclosure includes the keyboard, microprocessor board, and power supply components. Optical components (i.e., the lamp and photocell plus a preamplifier board) are contained in the head assembly. Wastewater enters the turbidimeter body and flows through a baffle network that forces a downward flow of the sample. At the bottom of the baffling, sample enters the center column of the bubble trap and rises up into the measuring chamber. Turbidity readings from the turbidimeters are transferred to an IBM PC by using a data acquisition system designed specifically for the purpose.

Influent wastewater for turbidity measurements is obtained from the influent pipe. A 6.3 mm (0.25 in) copper tube, which extends approximately 12.5 mm (0.5 in) inside the influent pipe, is mounted at the side of the influent pipe. Wastewater is delievered to the turbidimeter with a 6.3 mm (0.25 in) black rubber tube. A needle valve is used to adjust the wastewater sampling flow rate. In a similar manner, an effluent sample is obtained from the filtered water discharge line from the filter.

Head Loss Monitoring Equipment

The head loss through the medium is measured using the UNIMARKII pressure sensor manufactured by the Yokogawa Electric Corporation (see Fig. 3-8). A needle valve mounted on the line leading to the pressure sensor is used to reject the air trapped in the cell. The sensor is connected to the 6.3 mm (0.25 in) copper tube located on the inlet plenum of the filter. To check the results

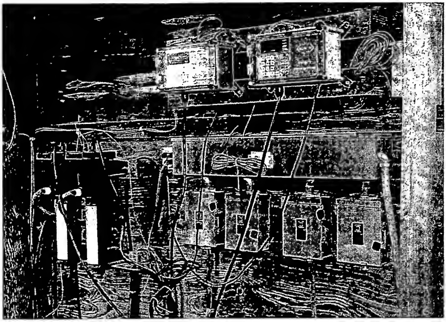

Figure 3-7
Turbidity meters used to monitor influent and effluent turbidity

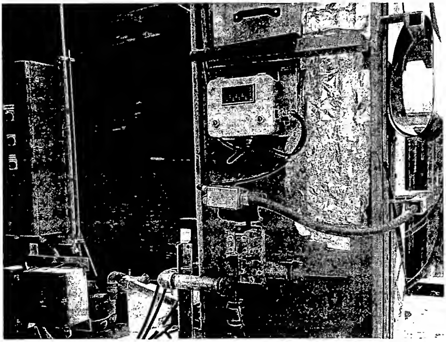

Figure 3-8
Pressure sensor used to monitor head loss development

obtained by the pressure sensor, a 0 to 5080 mm (0 to 200 in) of H_2O pressure gauge is also connected to the same tube at the same elevation with the sensor. Head loss readings, taken every second, are storred every minute using a "Rustrak Ranger 1" data logger.

4
METHODS AND PROCEDURES

The purpose of this section is to present and discuss the methods and procedures used to evaluate the performance of the Fuzzy Filter including: (1) the selection of filter bed configurations, (2) the operational procedures for the Fuzzy Filter, (3) analytical procedures, and (4) the data analysis procedures used in this study.

SELECTION OF FILTER BED CONFIGURATIONS

Based on preliminary testing, it was established that a filter bed comprised of 760 mm (30 in) of uncompacted filter medium would be needed for the effective operation of the Fuzzy Filter. Porosity and collector size of the medium are two important parameters that effect effluent water quality, along with the development of the head loss across the filter medium All three of these parameters can be altered by compressing the medium. To determine the feasible operational ranges for the compression ratio, four different compression ratios were evaluated: 0, 15, 30, and 40 percent. The corresponding depths of the filter bed are as follows: 760 mm (30 in), 650 mm (25.5 in), 530 mm (21 in), and 460 mm (18 in) at 0, 15, 30, and 40 percent bed compression, respectively.

OPERATIONAL PROCEDURES FOR THE FUZZY FILTER

A series of runs at four different filtration rates and four filter bed compression levels were performed with the Fuzzy Filter. Filtration rates, compression levels, and medium depths for each run are summarized in Table 4-1. The runs averaged about 24 hours in length. The procedures used to prepare the filter for each run were the same for all of the test runs.

Preparation For a Filter Run

Preparation for each run included: (1) setting the compression level of the filter medium, (2) setting the flow rate to the filter, (3) setting the backwash flow rate, (4) setting the terminal head loss value, (5) setting the turbidity sampling flow rate, (6) cleaning the turbidimeters, and (7) cleaning the influent manifolds and turbidity sampling lines.

Table 4-1
Summary of filtration runs for Fuzzy Filter

Run no.	Filtration rate L/m²•min	Filtration rate gal/ft²•min	Compression ratio %	Medium depth mm	Medium depth in	Estimated porosity %
1	205	5	0	760	30	92
2	205	5	15	650	25.5	90.5
3	205	5	30	530	21	88.5
4	205	5	40	460	18	87
5	410	10	0	760	30	92
6	410	10	15	650	25.5	90.5
7	410	10	30	530	21	88.5
8	410	10	40	460	18	87
9	820	20	0	760	30	92
10	820	20	15	650	25.5	90.5
11	820	20	30	530	21	88.5
12	820	20	40	460	18	87
13	1230	30	0	760	30	92
14	1230	30	15	650	25.5	90.5
15	1230	30	30	530	21	88.5
16	1230	30	40	460	18	87

Setting the compression level of the filter medium The position of the upper moveable perforated plate both during the filtration cycle and the backwash cycle are programmed in the control panel located at the side of the filter. The position of the upper plate during the filtration cycle is set according to the compression level desired. The position of the upper plate during the backwash cycle is set 125 mm (5 in) below the outflow piping for all of the runs, resulting in at least a 100 percent bed expansion for all bed depths tested.

Setting the Flow Rate to the Filter The flow rate is set using the gate valves on the pumps, and the gate valve at the left side of the loop leading to the filter (see Fig. 3-2).

Setting the Backwash Flow Rate The backwash flow rate is set using the ball valve on the right side of the bypass loop in the line leading to the filter. Backwash flow rate is set to approximately 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$) for all of the runs. The backwash flowrate was established based on the results of preliminary testing.

Setting the Terminal Head loss Value The terminal head loss value is set as the second alarm point of the UM04 controller device located at the main control panel of the filter system. Terminal head loss value is set to 2540 mm (100 in) of water for all of the runs.

Setting the Turbidity Sampling Flow Rate Influent turbidity sampling flow rate is set using the needle valve located on the copper tube mounted to the influent pipe. Effluent turbidity sampling flow rate is set using the ball valve located on the copper tube mounted to the effluent pipe. Turbidity sampling flow rates are set at about 400 mL/min for all of the runs (a sampling flow rate between 250 and 750 L/min is suggested by the manufacturer of the turbidimeters).

Cleaning the Turbidimeters Sediment tends to accumulate in the turbidimeter body, therefore turbidimeter bodies are drained using the plug at the bottom of the turbidimeter body, and the solids attached to the walls of the sampling zone are scrubbed manually. Photocell and the lens are cleaned carefully using a soft cloth twice during each filtration run.

Cleaning the Influent Manifolds and Turbidity Sampling Lines Sediment tends to accumulate on the influent manifolds at the secondary sedimentation tank, and in the turbidity sampling tubes. The manifolds are scrubbed manually to assure that all the circular inlets are open, and there are no attached solids left on the manifolds. Turbidity sampling tubes are taken apart from the copper tubes and the turbidimeter bodies, and flushed by using clean water to assure that there are no sediments left in the sampling tubes.

Filter Run Procedures

After completing the preparational procedures, monitoring of the run begins as the data acquisition system designed specifically for the purpose is turned on. Influent/effluent turbidities, and head loss through the filter medium are recorded every minute during entire run period.

The filter is checked every 3 to 6 hours to assure that desired experimental conditions are conserved throughout the runs. Influent flow rate remained almost constant throughout the runs. The turbidity sampling flow rate was set at about 400 mL/min, but varied by 50 to 100 mL/min throughout the runs, well within the range specified by the turbidity manufacturer for accurate readings. The head loss value detected by the pressure sensor is compared with the values read on the pressure gauge mounted at the same elevation as the pressure sensor. Values obtained with both devices were in agreement throughout the filter runs.

ANALYTICAL PROCEDURES

The analytial procedures used for the turbidity, suspended solids, and particle size are discussed below.

Turbidity Sample Analysis

Influent and effluent turbitidy measurements of the Fuzzy Filter are performed continuously by using 2 Hach Model 1720C low range process turbidimeters. The turbidimeters were calibrated at the beginning of the study according to the calibration kit method, which was briefly explained in the instruction manual. The accuracy of the readings were checked every week by using known turbidity solutions (which were prepared by using 20 NTU formazin standard), and by swapping the head assemblies of the 2 turbidimeters and comparing the values before and after swapping.

Suspended Solids

Suspended solids (SS) measurements were conducted during this study to correlate SS values to the turbidity readings. Suspended solids test were run according to Method 290 C outlined in Standard Methods (1992). Whatman GF/C glass fiber filters with a nominal pore size of 1.2 mm were used. The volume of the sample used for the SS test was assessed with separate tests. Low sample volumes generally result in a large scatter of the data while the use of overly large sample volumes can lead to autofiltration of the suspended matter. Autofiltration occurs when the solids accumulated in the upper layers, and on top of the filter, provide further filtering of the incoming solids. To assess an optimum sample volume for the Whatman GF/C filters, several different sample volume were tested for a wide range of influent turbidities. A volume of

200 mL was chosen, because it resulted in the least scatter for the SS readings with no apparent autofiltration.

PRESENTATION OF FILTER PERFOMANCE DATA

The performance of the Fuzzy Filter was tested at four filtration rates varying from 205 to 1230 $L/m^2{\bullet}min$ (5 to 30 $gal/ft^2{\bullet}min$) and at compression rates (0 to 40 percent compression) to determine ranges of feasible operation of the filter. The parameters that were monitored to assess the performance of the filter included: influent and effluent turbidity and head loss across the filter medium. Fractional turbidity removal data were derived from the turbidity data. The data for each filter run are presented as shown in Fig. 4-1, using filter run 7 (see table 4-1) as an example. A complete set of data plots for each run is presented in Appendix A.

Continuous Turbidity Removal

Influent and effluent turbidity was monitored continuously as described in Chap. 3. The readings from the turbidimeters were stored every minute by the use of the data acquisition system mentioned in Chap 3. Influent and effluent turbidity values versus filtration time are plotted in Fig. 4-1a. Influent and effluent turbidity data for all of the runs are presented in Figs. A-1a through A-16a in Appendix A.

Fractional Turbidity Removal

Fractional turbidity removal versus time data were obtained by using the influent/effluent turbidities versus time data, and the following relationship:

Removal efficiency = (1-effluent turbidity/influent turbidity)

The removal efficiency data for run 15 are shown in Fig. 4-1b. Removal efficiency data for all of the runs are presented in Figs. A-1b through A-16b in Appendix A.

Headloss Across The Filter Medium

Initial head loss and the development of head loss across the filter medium was monitored continuously as noted in Chap 3. Headloss data were stored every minute by using the data logger mentioned in Chap. 3. The development of headloss across the filter medium with time is presented in Fig 4-1c. Headloss data for all of the runs are presented in Figs. A-1c through A-16c in Appendix A.

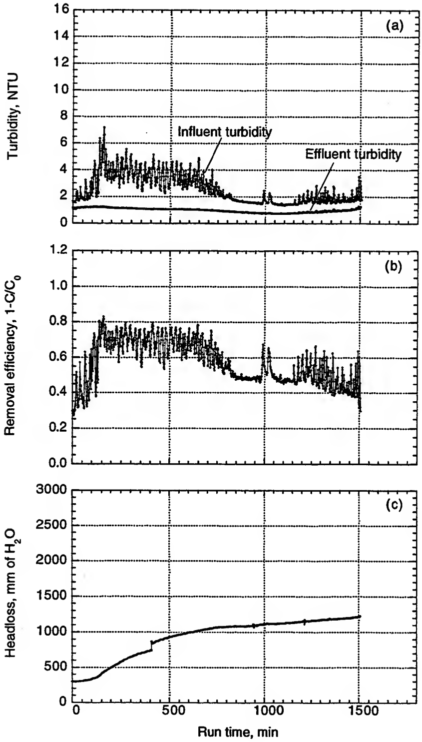

Figure 4-1
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

5
ANALYSIS AND DISCUSSION OF FILTRATION STUDY RESULTS

The purpose of this section is to present and discuss the results of the filtration studies including: (1) the effect of filtration rate and bed compression on turbidity removal, (2) turbidity removal efficiency, (3) the development of head loss through the filter medium, and (4) an assessment of the overall performance of the filter including backwash water requirements and total water production.

EFFECT OF FILTRATION RATE AND BED COMPRESSION ON TURBIDITY REMOVAL

Filtration rate, medium depth, collector size (usually defined as the average diameter of the medium grains), porosity, and the influent water quality are the principal parameters that effect effluent quality and development of head loss across the filter medium. The removal of turbidity with time for the different filtration rates and bed compression values is illustrated in Figs. A-1a, b through A-16a, b in Appendix A. The measured influent and effluent field turbidity data are plotted in Figs. A-1a through A-16a. The corresponding fractional turbidity removal data are reported in Figs A-1b through A-16b. In reviewing the influent and effluent turbidity data presented in these figures it is clear that as the degree of bed compression is increased, the overall turbidity removal increases. The effects of filtration rate and bed compression are examined in the following discussion.

Effect of Filtration Rate

At a filtration rate 205 L/m^2•min (5 gal/ft^2•min), the lowest rate evaluated in this study, filter ripening was observed. The ripening phenomenon that occurred at this flow rate is clearly shown in Figs. A-1a, b to A-4a, b. At this low filtration rate, flow was observed to occur primarily around the Fuzzy Filter medium, instead of through the medium as is the case at higher filtration rates. When the flow is around the filter medium, the corresponding removal efficiency is reduced because suspended solids in the liquid can move through the relatively large intersticies of the filter medium. However, with the passage of time as material starts to accumulate within the filter bed, the removal efficiency was observed to

increase (see Figs. A-1a, b to A-4a, b). Ripening was not as significant at higher filtration rates, because the removal occurred primarily through the medium and not around the medium.

When the flow is through the medium, the collector size (e.g., the size of the grains in a granular medium filter) can be defined as the average pore spacing within the structure of the Fuzzy Filter medium. Previously removed material decreases the collector size of the medium, resulting in an increase in the removal by interception and straining. When the flow is around the filter medium, the collector size is actually the Fuzzy Filter medium (defined as the nominal diameter of one Fuzzy Filter element). Because the difference between the initial collector size and the collector size at any time during the filtration cycle is much larger when the flow occurs around the medium, ripening becomes more important at low filtration rates.

Effect Of Filter Bed Compression

As noted previously, the porosity of the filter medium is an important variable in determining the filtered effluent quality. Because the Fuzzy Filter medium is compressible, the porosity, medium depth, and collector size all can be altered. As with other filtration technologies, there is maximum removal efficiency that can be achieved with the Fuzzy Filter, which is dependent on the characteristics of material being filtered (primarily colloidal material). Removal efficiency of the filter is expected to increase until some maximum level is reached as the level of compression is increased. This phenomenon was observed in the experiments performed at different compression rates. For example, average removal efficiency of the filter increased from 55 percent at 0 percent bed compression to 61 percent at 30 percent bed compression, when the flow rate was 205 L/m^2•min (5 gal/ft^2•min). Similarly average removal efficiency of the filter increased from 48 percent at 0 percent bed compression to 65 percent at 30 percent bed compression, when the flow rate was 410 L/m^2•min (10 gal/ft^2•min). The maximum removal efficiency of the Fuzzy Filter occurs at different compression levels as the filtration rate is increased and the characteristics of the effluent to be filtered change. Maximum removal efficiency was observed to occur at 40 percent bed compression at a filtration rate of 410 L/m^2•min (10 gal/ft^2•min), whereas 30 percent bed compression it was possible to produce the maximum

removal efficiency at filtration rates of 820 L/m^2•min (20 gal/ft^2•min), and 1230 L/m^2•min (30 gal/ft^2•min).

TURBIDITY REMOVAL EFFICIENCY

The evaluation of the Fuzzy Filter with respect to the removal of turbidity and the relationship between influent and effluent turbidity is considered in this section.

Removal Efficiency

Removal efficiency data are shown in Figs. A-1b through A-16b. The performance of the filter under different filtration conditions can be compared with each other easily after normalizing the turbidity data. It can be interpreted from the data plotted in Figs. A-1b through A-16b that removal efficiency is not effected significantly by the filtration rate, but is effected more by the compression level of the filter medium. Removal efficiency was maximized at 40 pecent bed compression when the flow rate was of 410 L/m^2•min (10 gal/ft^2•min) and at 30 percent bed compression for flow rates of both 820 L/m^2•min (20 gal/ft^2•min), and 1230 L/m^2•min (30 gal/ft^2•min). The reason for the maximum removal efficiency occurring at different compression levels when the flow rate is altered, is being investigated currently.

There is one disadvantage associated with reporting removal efficiency data as shown in shown in Figs. A-1b through A-16b. The reported removal efficiency will be lower when the influent turbidity is in the range from 1.5 to 3 NTU. At low influent turbidity values, the particle size distribution of the influent solids is shifted more towards the smaller colloidal sized particles than the typical particle size distribution observed when the influent turbidity is higher than 3 NTU. It should be noted that the turbidity of the secondary effluent from a typical activated sludge wastewater treatment plant is in the range from 3 to 8 NTU. The turbidity of the secondary effluent of the UCD wastewater treatment plant is often lower than 3 NTU for long periods of time (see Figs A-6a and A-11a). In these cases, the performance of the Fuzzy Filter should not be evaluated solely by the removal efficiency data. An important objective of this study is to determine the feasible ranges of compression level and the flow rate to obtain 2 NTU effluent turbidity.

Effluent Versus Influent Turbidity

To determine the influent turbidity value that can be filtered, without the use of chemicals, without exceeding the Title 22 turbidity requirements (2 NTU) an effluent versus influent turbidity analysis has been performed. The turbidity data from all the experimental filter runs have been aggregated in one turbidity unit increments. For example, all the filter effluent turbidities that correspond to influent turbidities of 3.5 to 4.499 NTU were read from the stored data for all the runs for a given filtration rate. The filter effluent turbidity readings are then averaged and reported at the average value of the filter influent turbidity (i.e., 4.0 NTU). The results of the effluent versus influent anlysis are plotted in Fig. 5-1 for the four filtration rates that were evaluated. As shown in Fig. 5-1, as the degree of bed compression increases, greater influent turbidity values can be handled at all of the filtration rates.

A general conclusion that can be reached is that the effluent turbidity will be equal to or lower than 2 NTU for influent turbidity values of up to approximately 8 NTU, when the flow rate is between 410 and 1230 $L/m^2{\bullet}min$ (10 to 30 $gal/ft^2{\bullet}min$) with a degree of bed compression of 30 percent. The performance of the Fuzzy Filter is consistent with the findings reported in Chap. 2 for the operation of conventional filters. It is important to note, however, that the Fuzzy Filter achieved the same performance levels at filtration rates varying from 6 to 15 as great as those used for the conventional filters.

HEAD LOSS DEVELOPMENT ACROSS THE FILTER MEDIUM

As noted previously, filtration rate, medium depth, collector size (usually defined as the average diameter of the medium grains), porosity, and the influent water quality are the principal parameters that effect effluent quality and development of head loss across the filter medium. The clean filter head loss, the development of head loss during filtration, and the development of head loss with the accumulation of solids are considered below.

Clean Filter Head Loss

The measured clean filter head loss across the filter medium as a function of the filtration rate and the degree of bed compression is shown in Fig. 5-2. As shown in Fig. 5-2, the initial head loss at flow rate of 205 $L/m^2{\bullet}min$ (5 $gal/ft^2{\bullet}min$) and 0 percent compression is 63 mm (2.5 in) of H_2O. This initial value increases linearly to a value of 127 mm (5 in) of H_2O at flow rate of 410 $L/m^2{\bullet}min$

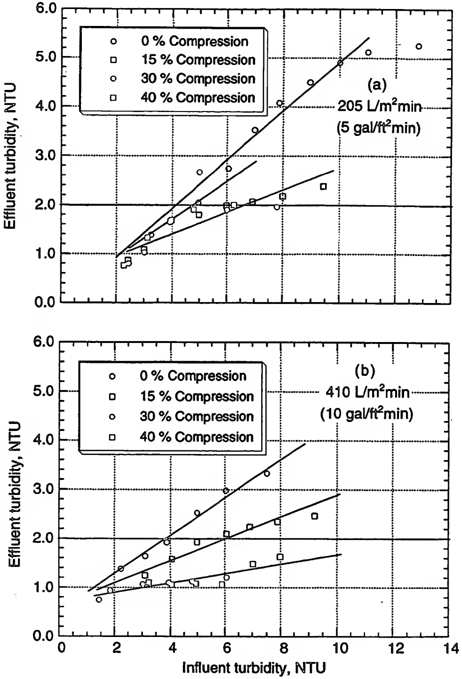

Figure 5-1

Effluent versus influent turbidity at various filtration rates: (a) 205 $L/m^2 \circ min$ (5 $gal/ft^2 \circ min$), (b) 410 $L/m^2 \circ min$ (10 $gal/ft^2 \circ min$), (c) 820 $L/m^2 \circ min$ (20 $gal/ft^2 \circ min$), (d) 1230 $L/m^2 \circ min$ (30 $gal/ft^2 \circ min$)

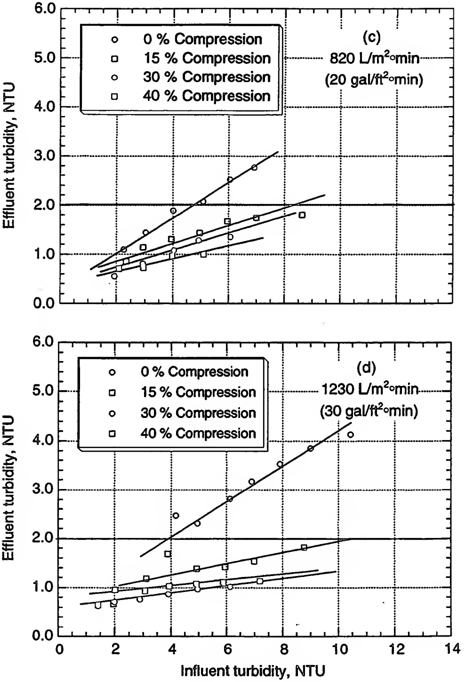

Figure 5-1 Continued
Effluent versus influent turbidity at various filtration rates: (a) 205 $L/m^2 \circ min$ (5 $gal/ft^2 \circ min$), (b) 410 $L/m^2 \circ min$ (10 $gal/ft^2 \circ min$), (c) 820 $L/m^2 \circ min$ (20 $gal/ft^2 \circ min$), (d) 1230 $L/m^2 \circ min$ (30 $gal/ft^2 \circ min$)

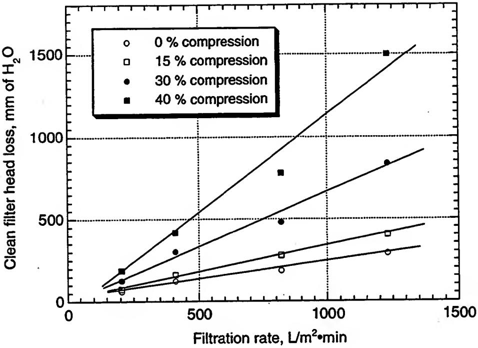

Figure 5-2
Initial clean bed head loss across the filter medium
versus filtration rate and bed compression

(10 gal/ft^2∘min) and 0 percent compression. The fact that the head loss increases linearly is an indication that the flow regime through the filter is laminar. The impact of compression is clearly evident in the curves plotted in Fig. 5-2. It should also be noted that the increase in head loss at any given filtration rate is not a linear function of the degree of compression.

Effect Of Filtration Rate and Bed Compression On Headloss

As mentioned above, increasing the degree of bed compression increases both the removal efficiency and the head loss occurring across the filter medium. There exists a compression level which assure the desired effluent quality, while keeping the head loss occurring across the filter medium in reasonable levels. The development of headloss with time for the different filtration rates and bed compression values is illustrated in Figs. A-1c through A-16c in Appendix A. As shown in these figures, depending on the filtration rate, there is gradual buildup of headloss with time as suspended solids accumulate within the filter. As some critical point is reached, the headloss starts to increase curvalinearly, which characteristic of removal by straining.

Head Loss Versus Suspended Solids Accumulation

The development of the head loss across the filter medium is related to the suspended solids accumulation in the medium. Suspended solids accumulation in the filter medium was calculated by using the influent/effluent turbidities versus time data, and the following relation:

$$\text{Suspended solids (g/L)} = 0.0023 \times \text{Turbidity (NTU)} \qquad (5\text{-}1)$$

The suspended solids accumulation in the medium at any time is calculated by the following mass balance equation:

$$SS_{acc} = 0.0023\,\Delta t\,\frac{Q}{V}\sum_{i=1}^{1=t/\Delta t}\left(Turb_{inf} - Turb_{eff}\right)_i \qquad (5\text{-}2)$$

where SS_{acc} = suspended solids accumulation at time t, g/m^3

Q = filtration rate, L/min

V = volume of filter medium, m^3

Δt = data collection frequency, min

$Turb_{inf}$ = influent turbidity, NTU

$Turb_{eff}$ = effluent turbidity, NTU

i = time index of the collected data

The correlation coefficient of 0.0023, developed during the earlier studies performed at the UCD wastewater treatment plant, was verified in this study. The development of headloss with time is shown in Figs. 5-3b and 5-4b. The corresponding development of head loss based on the amount of suspended solids retained within the filter is shown Figs. 5-3c and 5-4c. The relationship between the accumulation of solids and the development of head loss is currently under investigation.

OVERALL FILTER PERFORMANCE

In addition to the evaluation of the Fuzzy Filter with respect to the removal of turbidity and the development of headloss, other important considerations include the quantity of backwash water used relative to the amount of water processed. Summary data on the operation of the Fuzzy Filter including backwash water use and water production are presented in Table 5-1.

Backwash Water Requirements

Secondary effluent is used as the backwash water. A backwash rate of 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$) was observed to be sufficient for the cleanup of the medium. The cleanup operation of the filter medium takes approximately 30 minutes. The reduction of 30 minutes of backwash cycle time to approximately 20 minutes is currently under investigation. The percentage of the total water utilized for backwashing the Fuzzy Filter, as summarized in Column 5 of Table 5-1, was computed using the following expression.

$$\text{Backwash water, \%} = \frac{W_B}{W_F + W_B} \times 100 \qquad (5\text{-}3)$$

Where W_B = water used for backwashing the filter

W_F = total filtered water

Based on preliminary testing results, it appears that it may be possible to reduce the amount of backwash water to about one percent. The ability to reduce the amount of backwash water has significant cost implications with respect to the sizing of the wastewater treatment processes. By comparison, the typical

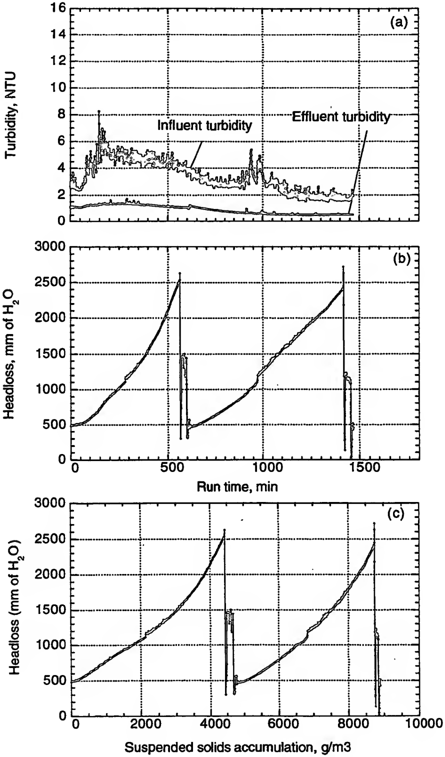

Figure 5-3
Filtration of activated sludge effluent at a filtration rate of 820 L/m²∘min (20 gal/ft²∘min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) headloss development versus time, and (c) headloss development versus suspended solids accumulation

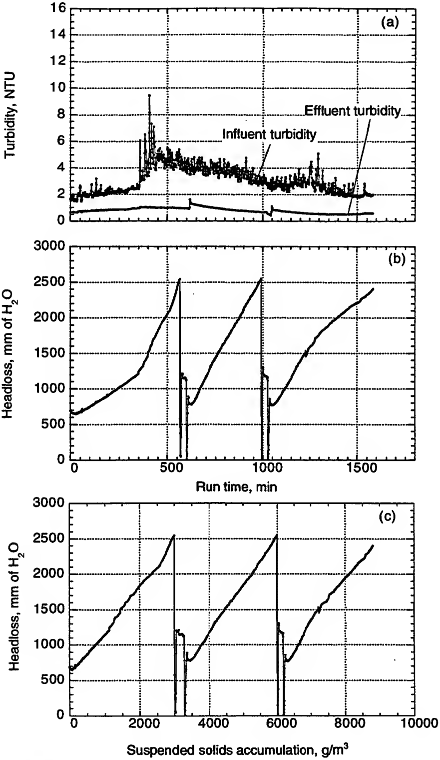

Figure 5-4
Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) headloss development versus time, and (c) headloss development versus suspended solids accumulation

Table 5-1
Summary performance data for Fuzzy Filter

Run no.	Filtration rate L/m²∘min	Filtration rate gal/ft²∘min	Comp. ratio, %	Back wash water, %	Total water produced L/m²∘d	Total water produced gal/ft²∘d
1	205	5	0	4.1	289,000	7,083
2	205	5	15	4.1	289,000	7,083
3	205	5	30	4.1	289,000	7,083
4	205	5	40	4.1	289,000	7,083
5	410	10	0	2.1	578,000	14,170
6	410	10	15	2.1	578,000	14,170
7	410	10	30	2.1	578,000	14,170
8	410	10	40	3.1	572,000	14,020
9	820	20	0	1.1	1,156,200	28,340
10	820	20	15	1.7	1,139,800	27,940
11	820	20	30	2.0	1,131,600	27,735
12	820	20	40	2.8	1,115,200	27,333
13	1,230	30	0	1.8	1,685,100	41,300
14	1,230	30	15	1.8	1,672,800	41,000
15	1,230	30	30	3.1	1,629,750	39,950
16	1,230	30	40	5.4	1,500,600	36,780

backwash percentage for most conventional effluent filters is from 6 to 15 percent.

Total Water Production

An important feature of any filtration system is the amount of water produced during a given time interval. In the filtration studies described in this report, the time interval is one day. Taking into account the water used for backwashing, the water production rate for various filtration rates and bed compression ratios is reported in the last two columns of Table 5-1. As shown, it was possible to produce 1,685,100 L/m²∘d (41,300 gal/ft²∘d), at a filtration rate of 1,230 L/m²∘min (30 gal/ft²∘min) and bed compression of 15 percent.

COMPARISON WITH OTHER FILTER TECHNOLOGIES

As illustrated in Fig. 5.1c and 5.1d, effluent turbidity values using the Fuzzy Filter, without chemical addition, will be equal to or lower than 2 NTU for influent turbitidy values of up to approximately 8 NTU, when the flow rate is between 820 and 1,230 L/m²•min (20 and 30 gal/ft²•min) at bed compression ratios between 15 and 40 percent. The perfomance of the Fuzzy Filter with respect to the removal of turbidity is similar to the perfomance of other filters (see Fig. 5-5) with one major exception: the filtration rate is more than 5 to 6 times the filtration rate of the other filters.

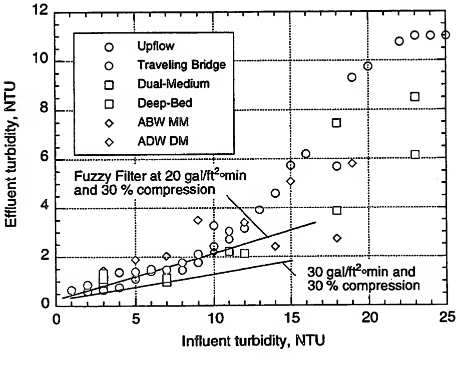

Figure 5-5
Comparison of effluent versus influent turbidity for Fuzzy Filter at 20 and 30 gal/ft²•min and 30 percent compression and various filters operated at 5 gal/ft²•min

6

CONCLUSIONS

The principal conclusions resulting from the evaluation of the Fuzzy Filter for the filtration of activated sludge effluent are as follows:

1. The Fuzzy Filter is effective for the filtration of effluent from an activated sludge treatment process.
2. The ability to compress the filter medium is a significant factor in the operation of the Fuzzy Filter, as the porosity of the bed can be modified to meet the characteristics of the liquid being filtered.
3. Because of the high porosity of the filter bed, significantly higher filtration rates [820 to 1,230 $L/m^2 \circ min$ (20 to 30 $gal/ft^2 \circ min$)] can be used effectively as compared to conventional granular medium filters [80 to 410 $L/m^2 \circ min$ (2 to 10 $gal/ft^2 \circ min$)].
4. Based on the observed removal efficiency and overall water production rate, the optimum filtration rate appears to be in the range from 820 to 1,230 $L/m^2 \circ min$ (20 to 30 $gal/ft^2 \circ min$) at bed compression values between 15 and 30 percent.
5. Effluent turbidity values, without chemical addition, will be equal to or lower than 2 NTU for influent turbitidy values of up to approximately 8 NTU, when the flow rate is between 820 and 1,230 $L/m^2 \circ min$ (20 and 30 $gal/ft^2 \circ min$) at bed compression ratios between 15 and 40 percent.
6. Secondary effluent is used as the backwash water. A flow rate of 410 $L/m^2 \circ min$ (10 $gal/ft^2 \circ min$) was observed to be sufficient to clean the filter medium.
7. The percentage of backwash water required at filtration rates of 820 and 1,230 $L/m^2 \circ min$ (20 to 30 $gal/ft^2 \circ min$) and bed compression values between 20 and 30 percent varied from 3.1 to 1.1 percent.
8. It was possible to produce 1,685,100 $L/m^2 \circ d$ (41,300 $gal/ft^2 \circ d$), at a filtration rate of 1,230 $L/m^2 \circ min$ (30 $gal/ft^2 \circ min$) and a bed compression of 15 percent.

REFERENCES

CSDLAC (1977) "Pomona Virus Study," County Sanitation Districts of Los Angeles County, Whittier, CA.

Lang, R., B. Weinschrott, and G. Tchobanoglous (1986) "Evaluation of the Aqua-Aerobics Automatic Backwash Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

Matsumoto, M. R., and G. Tchobanoglous (1981) "Evaluation of the Pulsed-Bed Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

Montgomery, J. M., Consulting Engineers, Inc. (1979) "Pilot Filtration Studies at the Tapia Water Reclamation Facility," Pasadena, CA.

Standard Methods for the Examination of Water and Wastewater (1992) 18th ed., American Public Health Association.

Tchobanoglous, G., and R. Eliassen (1970) "Filtration of Treated Sewage Effluent," Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 96, pp. 243-265.

Weinschrott, B., and G. Tchobanoglous (1986) "Evaluation of the Parkson DynaSand® Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

APPENDIX A
FILTER RUN DATA

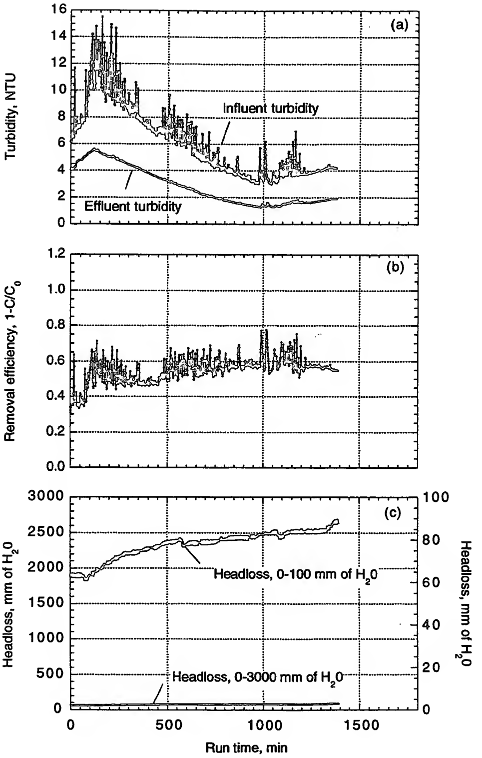

Figure A-1

Filtration of activated sludge effluent at a filtration rate of 205 L/m²•min (5 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

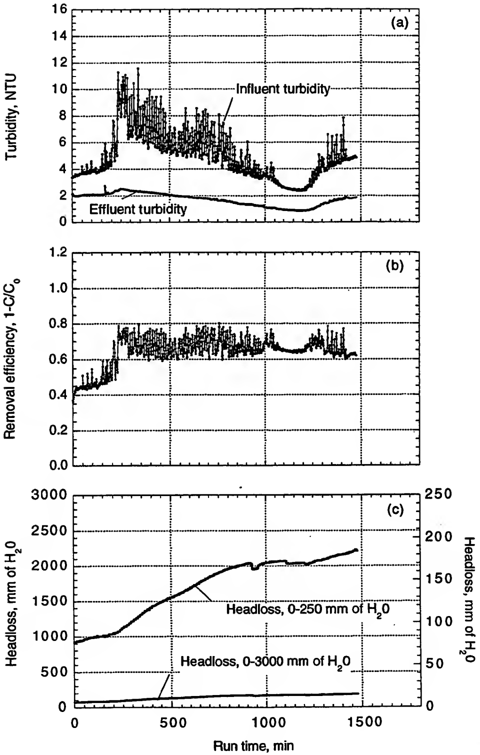

Figure A-2

Filtration of activated sludge effluent at a filtration rate of 205 L/m^2•min (5 gal/ft^2•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

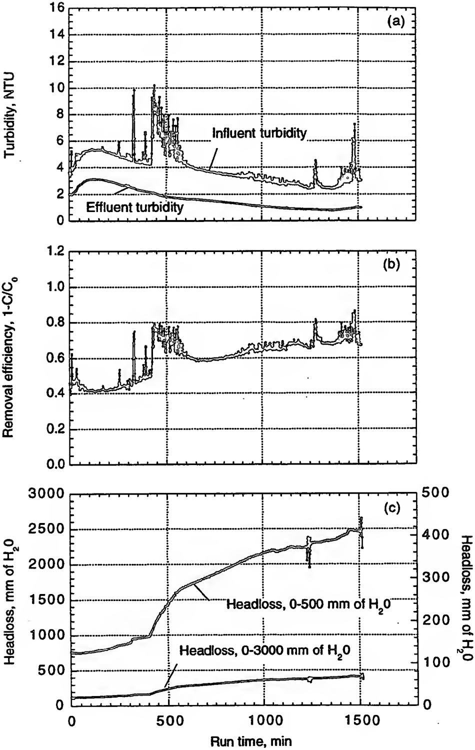

Figure A-3
Filtration of activated sludge effluent at a filtration rate of 205 L/m²•min (5 gal/ft²•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

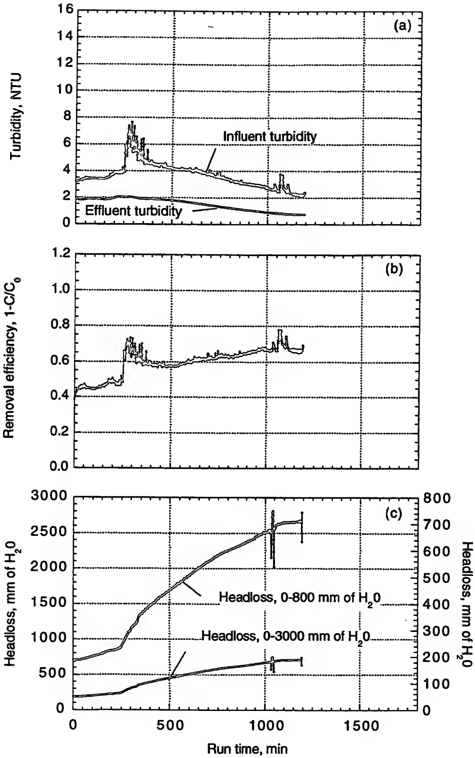

Figure A-4
Filtration of activated sludge effluent at a filtration rate of 205 L/m^2•min (5 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

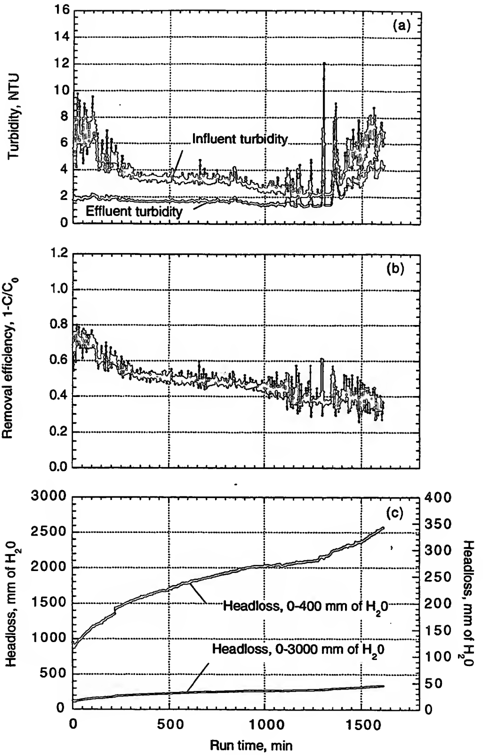

Figure A-5
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

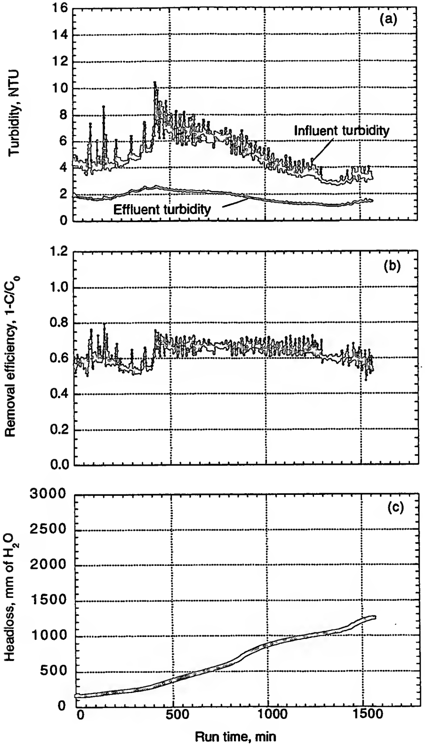

Figure A-6
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

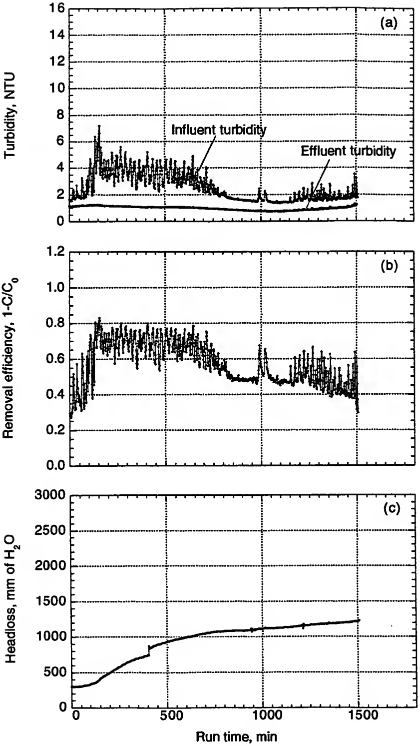

Figure A-7
Filtration of activated sludge effluent at a filtration rate of 410 L/m^2•min (10 gal/ft^2•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

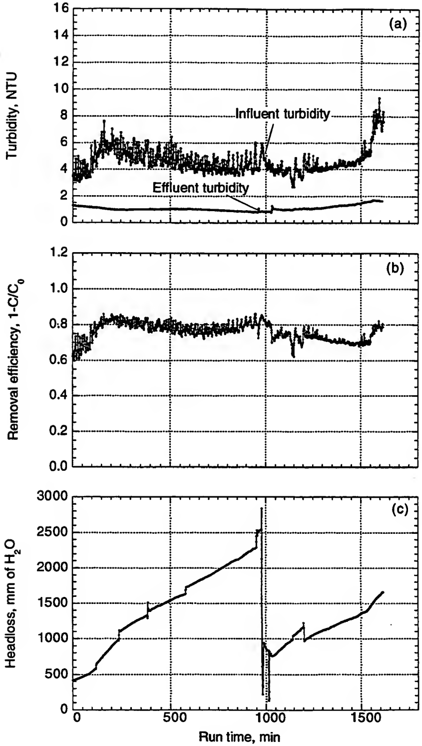

Figure A-8
Filtration of activated sludge effluent at a filtration rate of 410 L/m^2•min (10 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

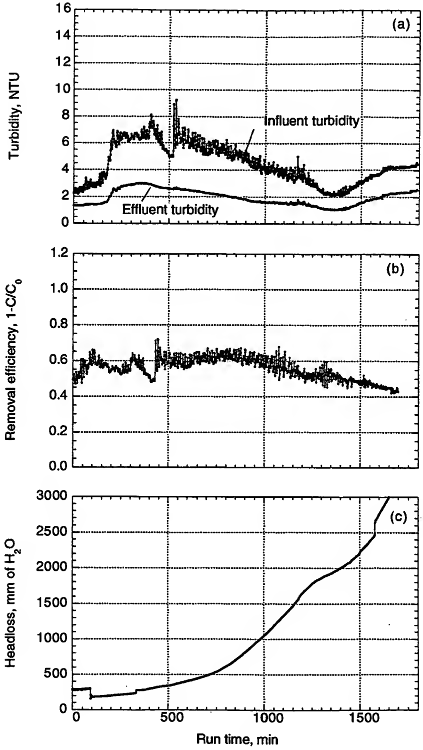

Figure A-9
Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

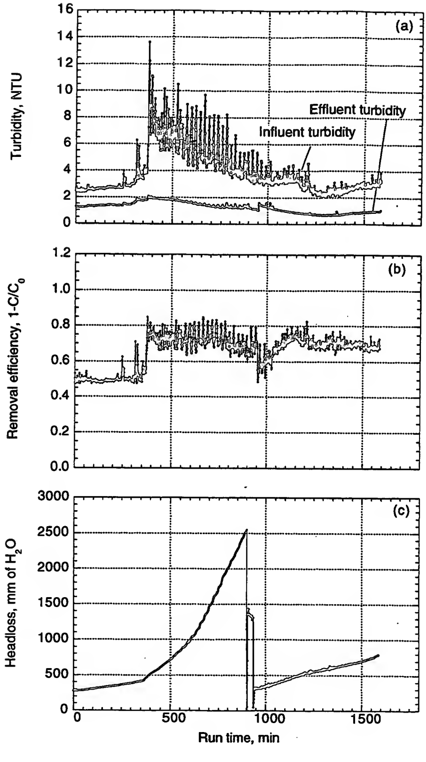

Figure A-10

Filtration of activated sludge effluent at a filtration rate of 820 L/m²•min (20 gal/ft²•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

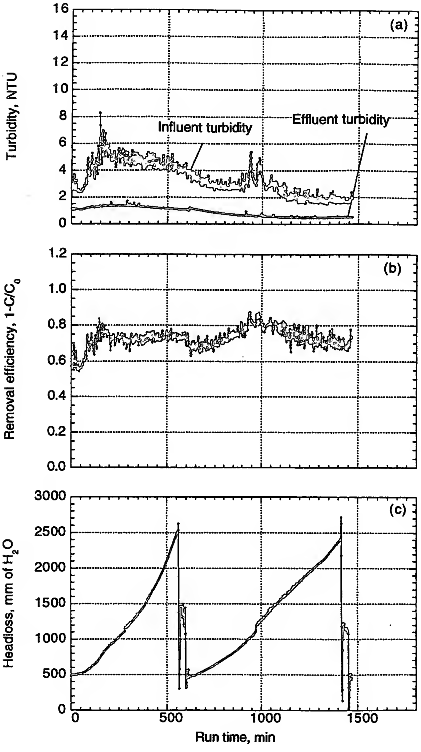

Figure A-11
Filtration of activated sludge effluent at a filtration rate of 820 L/m²ₒmin (20 gal/ft²ₒmin), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

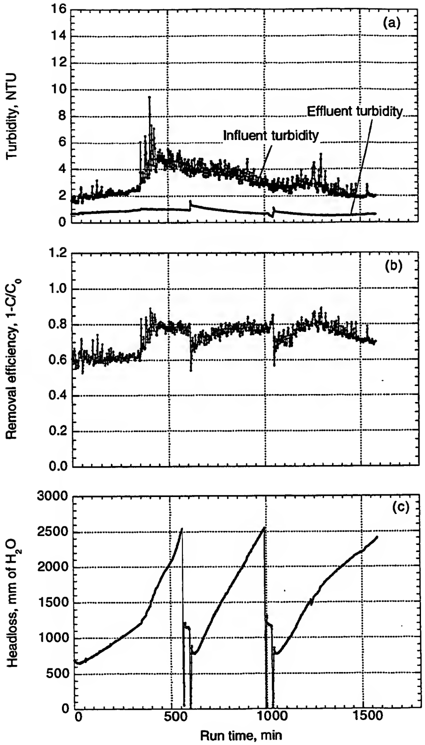

Figure A-12
Filtration of activated sludge effluent at a filtration rate of 820 L/m²•min (20 gal/ft²•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

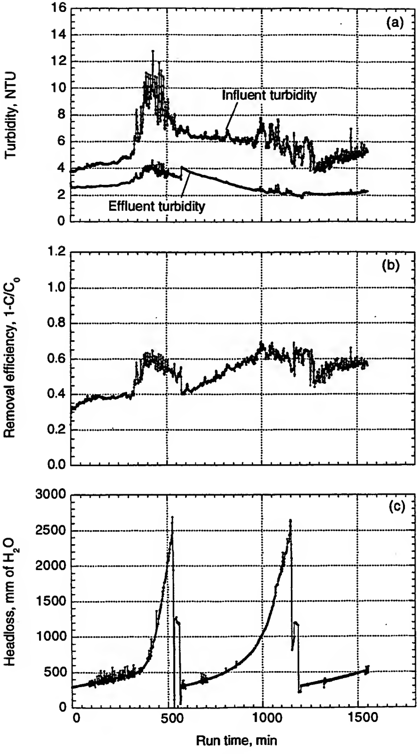

Figure A-13
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

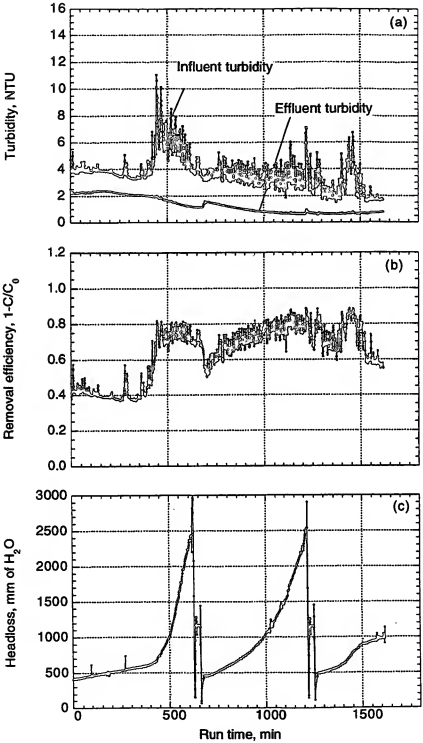

Figure A-14
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

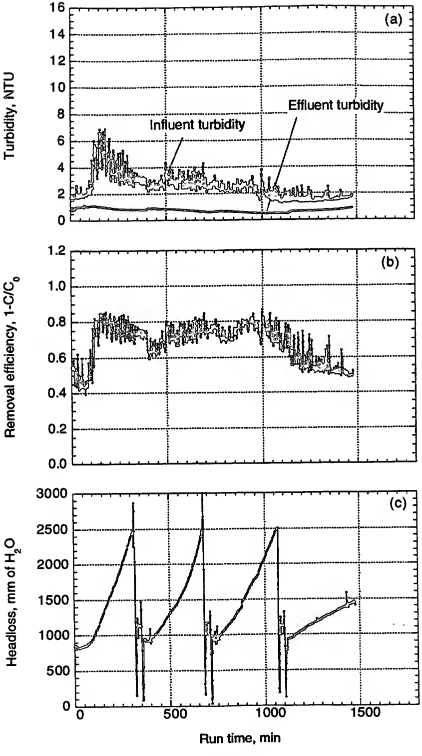

Figure A-15
Filtration of activated sludge effluent at a filtration rate of 1230 L/m²∘min (30 gal/ft²∘min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

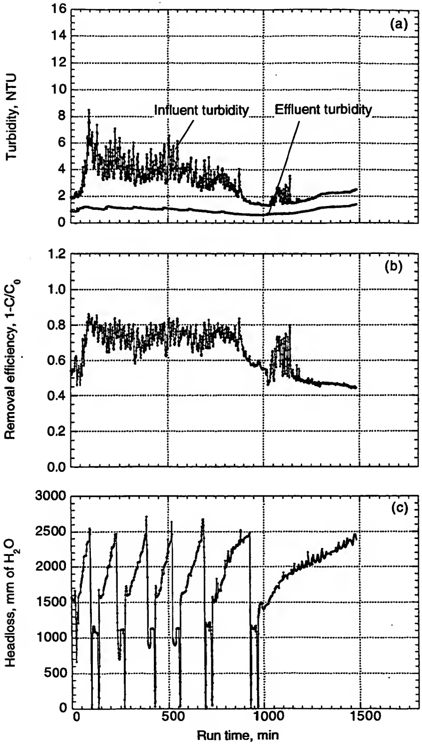

Figure A-16
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

Provisional Patent Application
U.S. Serial No. 60/032,643
Filed December 10, 1996

Exhibit 2

Submitted August 3, 2007

United States Patent File History

Tab Listings

A. References (if applicable)
  A1–U.S. References
  A2–Foreign References

B. Jacket (face of file, contents flap, index of claims, PTO 270, searched)

C. Printed Patent

D. Specification (serial no. Sheet, abstract, specification, claims)

E. Oath
  E1–Small Entity Status (if applicable)

F. Drawing Figures (if applicable)

G. USPTO/Applicant Correspondence

H. Original Patent Application (in cases of FWC)

Class	Subclass

ISSUE CLASSIFICATION

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TEAM 5

IAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMINER
)/032,643 ROVISIONAL	12/10/96				

ILLIAM F. DEN JR., HOMEWOOD, AL.

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Foreign priority claimed / 35 USC 119 conditions met	☐ yes ☐ no / ☐ yes ☐ no	AS FILED →	STATE OR COUNTRY	SHEETS DRWGS.	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.
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TITLE

HIGH RATE FILTRATION SYSTEM

U.S. DEPT. OF COMM./PAT. & TM—PTO-436L (Rev.12-94)

Form PTO-1625
(Rev 5/95)

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60/032643

PATENT APPLICATION

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ABSTRACT IS MISSING IN THE FILE.

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HIGH RATE FILTRATION SYSTEM

Field of the Invention

This invention relates to high rate filtration systems that typically are used as tertiary filters for wastewater treatment systems.

Background of the Invention

Masuda et al. U.S. Patent No. 5,248,415 discloses a high speed upward flow filtration apparatus that is useful as a tertiary filter for wastewater treatment systems. The filtration media comprises a plurality of crimpy fibrous lumps. The fibrous lumps have many bundled crimpy fibers formed by providing synthetic fibers of 20 to 200 denier with 2 to 10 crimps per inch. The bundled crimpy fibers are rung and bundled at the core portion thereof by a binding wire. The bundled crimpy fibers are rounded to provide the fibrous lump in the form of a substantial sphere having a diameter of 10 to 50 mm. A fiber having a higher specific gravity than water, for example, a polyvinylidene chloride fiber, is said to be optimal for the synthetic fiber to constitute the crimpy fiber. The fibers can also be made from polyvinylchloride, polyethylene fiber, or other synthetic fibers.

The fibrous lumps are disposed in the upward flow filtration apparatus between first and second perforated panels. The wastewater flows in an upward

direction through the fibrous lumps and suspended matter is captured by the individual fibrous lumps.

The first perforated panel is immovably mounted within the apparatus and the second perforated panel is movably mounted within the apparatus and spaced below the first perforated panel. The lower movable perforated panel, or bottom plate, is raised to compress the fibrous lumps to eliminate air gaps and to form a dense and uniform filter layer. The wastewater passes upwardly through the movable bottom plate and the filter layer and exits the top immovable plate. Fine solid materials in the upward flow progressively adhere to the filter layer from the lower portion to the upper portion thereof in that order. With progressive filtration, resistance to filtration is increased. The bottom movable plate is lowered from time to time when the filtration performance is reduced and it becomes necessary to clean the fibrous lumps.

Schreiber Corporation, the assignee of the invention described below, located in Birmingham, Alabama, is a licensee of the Masuda et al. patent and has denominated the subject matter thereof as its FUZZY FILTER™ high rate filtration system. However, the apparatus described in the Masuda et al. patent with the bottom plate movable has some difficulties associated with it. The Masuda device requires washing of the filter media on a frequent basis at a full flow rate equivalent to the flow rate of wastewater. A ram or screw for moving the bottom plate has to pass through the wastewater, the media, and the top stationary plate. The screw decreases the amount of room available from the media and potentially causes some channeling through the media in the region of the screw. The balls are constructed of a loose fiber and can be tied up in the screw as it turns. When the bottom plate is moved to compress the media, the lower layers of media become compressed to filter a small

micron size prior to the upper layers. Since the filter is operated in a backflow mode, the more compressed filter media is the first to see the wastewater. The filter clogs up fast because large particles and fines are trapped by the compressed lower layers of the filter media. The entire unit is shut down and the filter media is washed before the next cycle is begun.

Summary of the Invention

The invention provides a high rate filtration system in which fibrous lump filter media are contained between upper and lower perforated panels in which the upper panel, or top plate, is movable. With the top plate movable, the gradient of porosity is the opposite of that when only the bottom plate is movable. The filter media at the bottom, where the water enters in the upflow mode, is less compressed, and so larger particles are trapped by this filter media, but smaller particles travel through to the next layer. Each layer becomes progressively more compressed with a smaller micron size of filtration and removes smaller and smaller particles. The final upper layer of filtration media removes the smallest particles for which filtration is provided. Head requirements are initially somewhat greater than for the apparatus described in the Masuda et al. patent, but overall filtration efficiency is greatly improved.

The compressed layer of filter media at the top clogs less frequently than when the bottom layer of filter media is compressed because the top layer filters only the fines and not the large size particles in addition. Therefore, on a flow-per-day basis, the high rate filtration system of the invention typically is offstream less frequently and requires less washing of the media. Another advantage is that there is no necessity to provide a seal in an upper movable plate

for a ram or screw that is designed to move the lower movable plate.

Several cells can be built into each of the filters that can be independently controlled so that one filter cell can be shut down and cleaned while another is operating. The wash cycle can be done at a much lower flow rate with less water to be recycled, which means that the process can be run efficiently.

Detailed Description of the Invention

A high rate tertiary filtration system of the invention, denominated the FUZZY FILTER™ high rate filtration system, was evaluated under the direction and control of Schreiber Corporation by Dr. George Tchobanoglous and Onder Caliskaner at the Department of Civil and Environmental Engineering at the University of California, Davis. The results of that study and a description of the invention are provided below.

3
FILTRATION EQUIPMENT AND APPURTENANCES

The test filter and the associated equipment were located at the U.C. Davis campus wastewater treatment plant. The layout of the U.C. Davis wastewater treatment plant is shown in Fig. 3-1. The treatment plant is a conventional complete-mix activated sludge process that receives wastewater generated on campus. Effluent from the secondary clarifier number 1 was drawn and used as influent for this study. The Fuzzy Filter, provided by the Schreiber Corporation of Birmingham, AL, was used to carry out the study. The principal components of the filter test facility, described in this chapter, include: (1) the influent feed system, (2) the test filter, and (3) the filter appurtenances.

INFLUENT AND EFFLUENT PIPING SYSTEM

A flow diagram for the filtration system test setup is shown in Fig. 3-2. The influent and effluent piping systems are described below.

Influent Piping System

As shown in Fig. 3-2, secondary effluent from secondary clarifier number 1 of the campus wastewater treatment plant was used as the influent to the Fuzzy Filter. Two centrifugal pumps, 3.75 kW (5 hp) and 2.25 kW (3 hp), are used to deliver the treated wastewater from the secondary clarifier of the wastewater treatment plant to the Fuzzy Filter. Each of the two intake manifolds is located approximately 300 mm (12 in) below the water surface just inside the effluent weir. Each manifold is made up of a 63-mm (2.5-in) diameter PVC pipe, 3.0 m (10 ft) long with 30-16 mm (5/8 in) circular inlets located at the midpoint of the pipe. The manifolds are attached to gate valves, which are used to control the pumping rate. Influent wastewater is then delivered by a 75-mm (3-in) PVC pipe, which is connected with a tee to a bypass loop located infront of the filter.

The bypass loop is equipped with a ball valve at the right side of the loop, which is used to regulate the backwash rate, and a gate valve followed by an automatic ball valve on the left side of the loop. The gate valve is used to regulate the filtration rate, and the automatic ball valve is used to divert flow to the right side

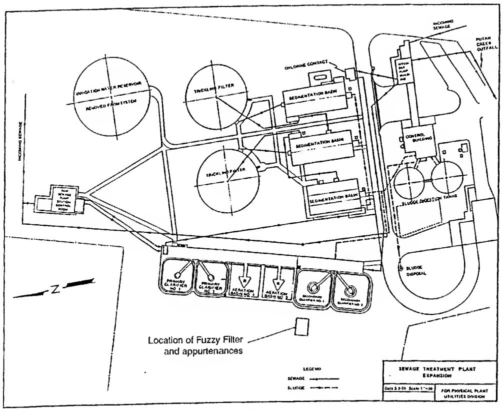

Figure 3-1

Layout of ~~the University of California at Davis campus~~ wastewater treatment facilities. Effluent from secondary clarifier number 1 of the activated sludge treatment plant was used as the influent for the Fuzzy Filter.

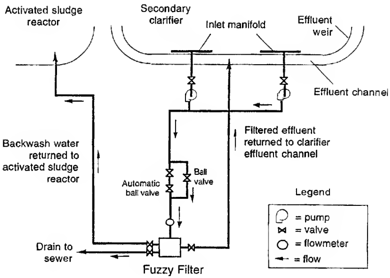

Figure 3-2
Flow diagram for the Fuzzy Filter test program

of the bypass loop, where the backwash rate is adjusted, as soon as the backwash cycle starts. A magnetic flow meter is located in the influent line following the bypass loop. A 6.5 mm (0.25 in) copper tube, is mounted at the side of the influent pipe to collect samples for the influent turbidity readings.

Effluent Piping System

The outlet piping from the filter consists of two 150 mm (6 in) PVC pipelines, and one 100 mm (4 in) (see Fig. 3-2). Filtered effluent from the filter is delivered back to the effluent channel of the secondary clarifier by the pipeline at the right side of the filter. Backwash water is returned to the activated sludge tank with the pipeline located at the left side of the filter. The 100 mm (4 in) line at the bottom of the filter is used to drain the filter, if required.

THE EXPERIMENTAL FILTER

In the Fuzzy Filter, shown in Fig. 3-3, a synthetic fiber porous material is used as the filter medium, instead of a conventional granular material. This filter has been designated the "Fuzzy Filter" by Schreiber Corporation, the manufacturer of the patented filtration process, because of the appearance of the filter medium. A description of the filter and its operation, the characteristics of the filter medium, and the air delivery system for filter backwashing are discussed below.

Description of the Filter Operation

A schematic of the filter is shown in Fig. 3-4. Because of its low density, the filter medium is retained between two perforated plates. Because the filter medium is compressible, the porosity of the filter bed can be altered according to the characteristics of the influent, by adjusting the position of the upper movable plate. The filter medium also represents a departure from conventional filter mediums in that the fluid to be filtered flows through the medium as opposed to flowing around the filtering medium, as in sand and anthracite filters.

During the filtration cycle, secondary effluent is introduced in the bottom of the filter into a plenum. The inlet plenum assures uniform distribution of the flow. The influent wastewater flows upward through the filter medium, and is discharged from the top of the filter. The filtration cycle is interrupted for backwashing, when the head loss through the filter medium reaches a preset maximum allowable level (i.e., terminal head loss), or the effluent quality deteriorates to an unacceptable level, usually referred as "breakthrough".

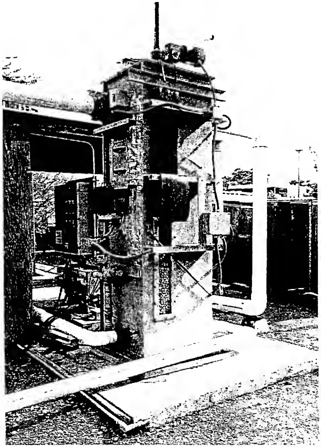

Figure 3-3
View of the Fuzzy Filter located at the UC Davis campus wastewater treatment plant

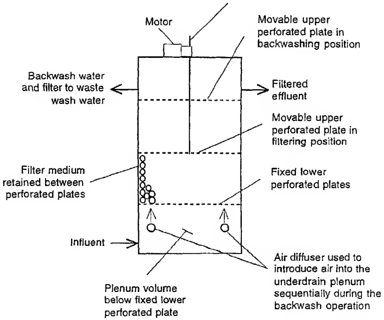

Figure 3-4
Schematic diagram of the operation of the Fuzzy Filter

At the inception of the backwash cycle, the flow is diverted to the backwash water line (see Fig 3-4) and the upper plate is moved up mechanically to increase the bed volume for backwashing. The backwash water is returned to the activated sludge process. While the secondary effluent flow continues to flow up through the filter, air is introduced below the lower perforated plate sequentially first from the left side and then the right side of the filter. The air creates turbulence and shear forces as it moves up through the expanded filter bed, which help to remove the accumulated material from the medium. The complete backwash cycle takes approximately 30 minutes. To start the next filtration cycle, upper perforated plate is returned to its original position, and the filter is flushed to waste for 1 minute to eliminate the discharge of any residual backwash solids with filtered effluent. Filter is put back into the filtration cycle upon the diversion of the flow from the backwash line to the effluent line. Summary information on the Fuzzy Filter used in this study is presented in Table 3-1.

Characteristics of the Filter Medium

The synthetic filter medium has a quasi spherical shape, and is approximately 30 mm (1.25 in) in diameter (see Fig. 3-5). The medium has some unusual properties; the medium is highly porous, and compressible. These two uncommon properties are unique and offer significant advantages over existing filtration technologies employing a solid medium. Based on displacement tests, the porosity of the filter medium itself is estimated to be about 88-90 percent. The porosity of the uncompacted filter bed is about 92 to 94 percent. The density of the medium is slightly greater than that of water. Experimental studies are underway to estimate the effective collector size of the medium. Porosity and collector size of the medium are two important parameters that effect effluent water quality, along with the development of the head loss across the filter medium. Because the filter medium is compressible, the porosity and the collector size of the medium can be altered according to the characteristics of the influent in various applications. It is also possible to alter the porosity and the collector size of the medium during the filtration cycle, to overcome the effect of the variations in daily influent water quality on the effluent quality.

Table 3-1
Summary information on the Fuzzy Filter test unit

Item	Unit	Value
Filter Characteristics		
Overall outside		
Length	m (ft)	0.85 (2.75)
Width	m (ft)	0.74 (2.4)
Height	m (ft)	3 (9.85)
Filtration area		
Length	m (ft)	0.7 (2.3)
Width	m (ft)	0.7 (2.3)
Area	m^2 (ft^2)	0.49 (5.25)
Piping		
Inlet	mm (in)	100 (4)
Filtered water outlet	mm (in)	150 (6)
Backwash water outlet	mm (in)	150 (6)
Filter drain	mm (in)	100 (4)
Filter Operation		
Nominal flow rates	L/min (gal/min)	100-795 (26-210)
Nominal filtration rates	L/m^2•min (gal/ft^2•min)	205-1230 (5-30)
Maximum terminal headloss	mm (in)	2,540 (100)
Nominal backwash rate	L/m^2•min (gal/ft^2•min)	410 (10)

Air Delivery System for Filter Backwashing

Air is supplied to the filter during the backwash cycle with a 5.6 kW (7.5 hp) Rotron centrigugal blower (see Fig. 3-6). Air is delivered to the filter through a 50 mm (2 in) stainless steel pipe, and introduced sequentially from the left and right sides of the filter below the lower perforated plate. The air flow is sequenced by means of two electormechanical valves located on the two air lines leading to the filter.

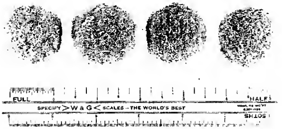

Figure 3-5
Fuzzy Filter filtering medium

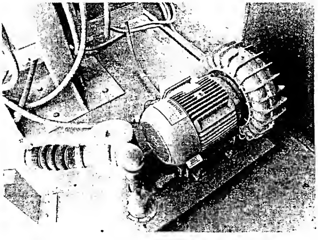

Figure 3-6
Air compressor used to provide air for the backwashing operation

FILTER APPURTENANCES

The principal fiter appurtenances include the (1) turbidity monitoring equipment and (2) head loss monitoring equipment.

Turbidity Monitoring Equipment

Two Hach 1720 C low range, continuous flow type nephelometric turbidimeters are used for turbidity monitoring. The turbidimeter consists of a control unit, head assembly, and turbidimeter body (see Fig. 3-7). All the electronics are contained in the control unit and head assembly. The control unit enclosure includes the keyboard, microprocessor board, and power supply components. Optical components (i.e., the lamp and photocell plus a preamplifier board) are contained in the head assembly. Wastewater enters the turbidimeter body and flows through a baffle network that forces a downward flow of the sample. At the bottom of the baffling, sample enters the center column of the bubble trap and rises up into the measuring chamber. Turbidity readings from the turbidimeters are transferred to an IBM PC by using a data acquisition system designed specifically for the purpose.

Influent wastewater for turbidity measurements is obtained from the influent pipe. A 6.3 mm (0.25 in) copper tube, which extends approximately 12.5 mm (0.5 in) inside the influent pipe, is mounted at the side of the influent pipe. Wastewater is delievered to the turbidimeter with a 6.3 mm (0.25 in) black rubber tube. A needle valve is used to adjust the wastewater sampling flow rate. In a similar manner, an effluent sample is obtained from the filtered water discharge line from the filter.

Head Loss Monitoring Equipment

The head loss through the medium is measured using the UNIMARKII pressure sensor manufactured by the Yokogawa Electric Corporation (see Fig. 3-8). A needle valve mounted on the line leading to the pressure sensor is used to reject the air trapped in the cell. The sensor is connected to the 6.3 mm (0.25 in) copper tube located on the inlet plenum of the filter. To check the results

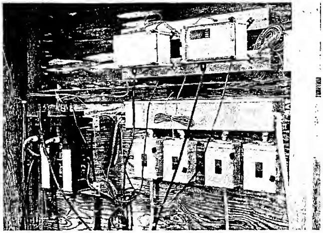

Figure 3-7
Turbidity meters used to monitor influent and effluent turbidity

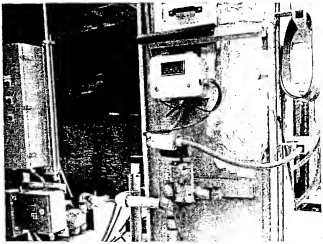

Figure 3-8
Pressure sensor used to monitor head loss development

obtained by the pressure sensor, a 0 to 5080 mm (0 to 200 in) of H_2O pressure gauge is also connected to the same tube at the same elevation with the sensor. Head loss readings, taken every second, are storred every minute using a "Rustrak Ranger 1" data logger.

4
METHODS AND PROCEDURES

The purpose of this section is to present and discuss the methods and procedures used to evaluate the performance of the Fuzzy Filter including: (1) the selection of filter bed configurations, (2) the operational procedures for the Fuzzy Filter, (3) analytical procedures, and (4) the data analysis procedures used in this study.

SELECTION OF FILTER BED CONFIGURATIONS

Based on preliminary testing, it was established that a filter bed comprised of 760 mm (30 in) of uncompacted filter medium would be needed for the effective operation of the Fuzzy Filter. Porosity and collector size of the medium are two important parameters that effect effluent water quality, along with the development of the head loss across the filter medium All three of these parameters can be altered by compressing the medium. To determine the feasible operational ranges for the compression ratio, four different compression ratios were evaluated: 0, 15, 30, and 40 percent. The corresponding depths of the filter bed are as follows: 760 mm (30 in), 650 mm (25.5 in), 530 mm (21 in), and 460 mm (18 in) at 0, 15, 30, and 40 percent bed compression, respectively.

OPERATIONAL PROCEDURES FOR THE FUZZY FILTER

A series of runs at four different filtration rates and four filter bed compression levels were performed with the Fuzzy Filter. Filtration rates, compression levels, and medium depths for each run are summarized in Table 4-1. The runs averaged about 24 hours in length. The procedures used to prepare the filter for each run were the same for all of the test runs.

Preparation For a Filter Run

Preparation for each run included: (1) setting the compression level of the filter medium, (2) setting the flow rate to the filter, (3) setting the backwash flow rate, (4) setting the terminal head loss value, (5) setting the turbidity sampling flow rate, (6) cleaning the turbidimeters, and (7) cleaning the influent manifolds and turbidity sampling lines.

Table 4-1
Summary of filtration runs for Fuzzy Filter

Run no.	Filtration rate L/m²•min	Filtration rate gal/ft²•min	Compression ratio %	Medium depth mm	Medium depth in	Estimated porosity %
1	205	5	0	760	30	92
2	205	5	15	650	25.5	90.5
3	205	5	30	530	21	88.5
4	205	5	40	460	18	87
5	410	10	0	760	30	92
6	410	10	15	650	25.5	90.5
7	410	10	30	530	21	88.5
8	410	10	40	460	18	87
9	820	20	0	760	30	92
10	820	20	15	650	25.5	90.5
11	820	20	30	530	21	88.5
12	820	20	40	460	18	87
13	1230	30	0	760	30	92
14	1230	30	15	650	25.5	90.5
15	1230	30	30	530	21	88.5
16	1230	30	40	460	18	87

Setting the compression level of the filter medium The position of the upper moveable perforated plate both during the filtration cycle and the backwash cycle are programmed in the control panel located at the side of the filter. The position of the upper plate during the filtration cycle is set according to the compression level desired. The position of the upper plate during the backwash cycle is set 125 mm (5 in) below the outflow piping for all of the runs, resulting in at least a 100 percent bed expansion for all bed depths tested.

Setting the Flow Rate to the Filter The flow rate is set using the gate valves on the pumps, and the gate valve at the left side of the loop leading to the filter (see Fig. 3-2).

Setting the Backwash Flow Rate The backwash flow rate is set using the ball valve on the right side of the bypass loop in the line leading to the filter. Backwash flow rate is set to approximately 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$) for all of the runs. The backwash flowrate was established based on the results of preliminary testing.

Setting the Terminal Head loss Value The terminal head loss value is set as the second alarm point of the UM04 controller device located at the main control panel of the filter system. Terminal head loss value is set to 2540 mm (100 in) of water for all of the runs.

Setting the Turbidity Sampling Flow Rate Influent turbidity sampling flow rate is set using the needle valve located on the copper tube mounted to the influent pipe. Effluent turbidity sampling flow rate is set using the ball valve located on the copper tube mounted to the effluent pipe. Turbidity sampling flow rates are set at about 400 mL/min for all of the runs (a sampling flow rate between 250 and 750 L/min is suggested by the manufacturer of the turbidimeters).

Cleaning the Turbidimeters Sediment tends to accumulate in the turbidimeter body, therefore turbidimeter bodies are drained using the plug at the bottom of the turbidimeter body, and the solids attached to the walls of the sampling zone are scrubbed manually. Photocell and the lens are cleaned carefully using a soft cloth twice during each filtration run.

Cleaning the Influent Manifolds and Turbidity Sampling Lines Sediment tends to accumulate on the influent manifolds at the secondary sedimentation tank, and in the turbidity sampling tubes. The manifolds are scrubbed manually to assure that all the circular inlets are open, and there are no attached solids left on the manifolds. Turbidity sampling tubes are taken apart from the copper tubes and the turbidimeter bodies, and flushed by using clean water to assure that there are no sediments left in the sampling tubes.

Filter Run Procedures

After completing the preparational procedures, monitoring of the run begins as the data acquisition system designed specifically for the purpose is turned on. Influent/effluent turbidities, and head loss through the filter medium are recorded every minute during entire run period.

The filter is checked every 3 to 6 hours to assure that desired experimental conditions are conserved throughout the runs. Influent flow rate remained almost constant throughout the runs. The turbidity sampling flow rate was set at about 400 mL/min, but varied by 50 to 100 mL/min throughout the runs, well within the range specified by the turbidity manufacturer for accurate readings. The head loss value detected by the pressure sensor is compared with the values read on the pressure gauge mounted at the same elevation as the pressure sensor. Values obtained with both devices were in agreement throughout the filter runs.

ANALYTICAL PROCEDURES

The analytial procedures used for the turbidity, suspended solids, and particle size are discussed below.

Turbidity Sample Analysis

Influent and effluent turbitidy measurements of the Fuzzy Filter are performed continuously by using 2 Hach Model 1720C low range process turbidimeters. The turbidimeters were calibrated at the beginning of the study according to the calibration kit method, which was briefly explained in the instruction manual. The accuracy of the readings were checked every week by using known turbidity solutions (which were prepared by using 20 NTU formazin standard), and by swapping the head assemblies of the 2 turbidimeters and comparing the values before and after swapping.

Suspended Solids

Suspended solids (SS) measurements were conducted during this study to correlate SS values to the turbidity readings. Suspended solids test were run according to Method 290 C outlined in Standard Methods (1992). Whatman GF/C glass fiber filters with a nominal pore size of 1.2 mm were used. The volume of the sample used for the SS test was assessed with separate tests. Low sample volumes generally result in a large scatter of the data while the use of overly large sample volumes can lead to autofiltration of the suspended matter. Autofiltration occurs when the solids accumulated in the upper layers, and on top of the filter, provide further filtering of the incoming solids. To assess an optimum sample volume for the Whatman GF/C filters, several different sample volume were tested for a wide range of influent turbidities. A volume of

200 mL was chosen, because it resulted in the least scatter for the SS readings with no apparent autofiltration.

PRESENTATION OF FILTER PERFOMANCE DATA

The performance of the Fuzzy Filter was tested at four filtration rates varying from 205 to 1230 $L/m^2 \cdot min$ (5 to 30 $gal/ft^2 \cdot min$) and at compression rates (0 to 40 percent compression) to determine ranges of feasible operation of the filter. The parameters that were monitored to assess the performance of the filter included: influent and effluent turbidity and head loss across the filter medium. Fractional turbidity removal data were derived from the turbidity data. The data for each filter run are presented as shown in Fig. 4-1, using filter run 7 (see table 4-1) as an example. A complete set of data plots for each run is presented in Appendix A.

Continuous Turbidity Removal

Influent and effluent turbidity was monitored continuously as described in Chap. 3. The readings from the turbidimeters were stored every minute by the use of the data acquisition system mentioned in Chap 3. Influent and effluent turbidity values versus filtration time are plotted in Fig. 4-1a. Influent and effluent turbidity data for all of the runs are presented in Figs. A-1a through A-16a in Appendix A.

Fractional Turbidity Removal

Fractional turbidity removal versus time data were obtained by using the influent/effluent turbidities versus time data, and the following relationship:

Removal efficiency = (1-effluent turbidity/influent turbidity)

The removal efficiency data for run 15 are shown in Fig. 4-1b. Removal efficiency data for all of the runs are presented in Figs. A-1b through A-16b in Appendix A.

Headloss Across The Filter Medium

Initial head loss and the development of head loss across the filter medium was monitored continuously as noted in Chap 3. Headloss data were stored every minute by using the data logger mentioned in Chap. 3. The development of headloss across the filter medium with time is presented in Fig 4-1c. Headloss data for all of the runs are presented in Figs. A-1c through A-16c in Appendix A.

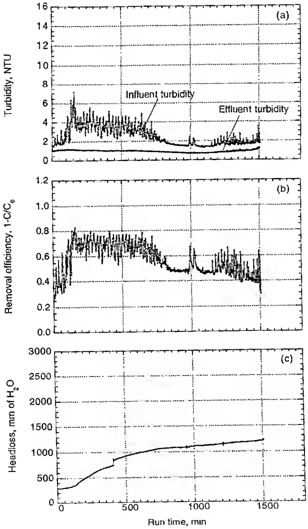

Figure 4-1
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

5
ANALYSIS AND DISCUSSION OF FILTRATION STUDY RESULTS

The purpose of this section is to present and discuss the results of the filtration studies including: (1) the effect of filtration rate and bed compression on turbidity removal, (2) turbidity removal efficiency, (3) the development of head loss through the filter medium, and (4) an assessment of the overall performance of the filter including backwash water requirements and total water production.

EFFECT OF FILTRATION RATE AND BED COMPRESSION ON TURBIDITY REMOVAL

Filtration rate, medium depth, collector size (usually defined as the average diameter of the medium grains), porosity, and the influent water quality are the principal parameters that effect effluent quality and development of head loss across the filter medium. The removal of turbidity with time for the different filtration rates and bed compression values is illustrated in Figs. A-1a, b through A-16a, b in Appendix A. The measured influent and effluent field turbidity data are plotted in Figs. A-1a through A-16a. The corresponding fractional turbidity removal data are reported in Figs A-1b through A-16b. In reviewing the influent and effluent turbidity data presented in these figures it is clear that as the degree of bed compression is increased, the overall turbidity removal increases. The effects of filtration rate and bed compression are examined in the following discussion.

Effect of Filtration Rate

At a filtration rate 205 L/m^2•min (5 gal/ft^2•min), the lowest rate evaluated in this study, filter ripening was observed. The ripening phenomenon that occurred at this flow rate is clearly shown in Figs. A-1a, b to A-4a, b. At this low filtration rate, flow was observed to occur primarily around the Fuzzy Filter medium, instead of through the medium as is the case at higher filtration rates. When the flow is around the filter medium, the corresponding removal efficiency is reduced because suspended solids in the liquid can move through the relatively large intersticies of the filter medium. However, with the passage of time as material starts to accumulate within the filter bed, the removal efficiency was observed to

increase (see Figs. A-1a, b to A-4a, b). Ripening was not as significant at higher filtration rates, because the removal occurred primarily through the medium and not around the medium.

When the flow is through the medium, the collector size (e.g., the size of the grains in a granular medium filter) can be defined as the average pore spacing within the structure of the Fuzzy Filter medium. Previously removed material decreases the collector size of the medium, resulting in an increase in the removal by interception and straining. When the flow is around the filter medium, the collector size is actually the Fuzzy Filter medium (defined as the nominal diameter of one Fuzzy Filter element). Because the difference between the initial collector size and the collector size at any time during the filtration cycle is much larger when the flow occurs around the medium, ripening becomes more important at low filtration rates.

Effect Of Filter Bed Compression

As noted previously, the porosity of the filter medium is an important variable in determining the filtered effluent quality. Because the Fuzzy Filter medium is compressible, the porosity, medium depth, and collector size all can be altered. As with other filtration technologies, there is maximum removal efficiency that can be achieved with the Fuzzy Filter, which is dependent on the characteristics of material being filtered (primarily colloidal material). Removal efficiency of the filter is expected to increase until some maximum level is reached as the level of compression is increased. This phenomenon was observed in the experiments performed at different compression rates. For example, average removal efficiency of the filter increased from 55 percent at 0 percent bed compression to 61 percent at 30 percent bed compression, when the flow rate was 205 $L/m^2 \cdot min$ (5 $gal/ft^2 \cdot min$). Similarly average removal efficiency of the filter increased from 48 percent at 0 percent bed compression to 65 percent at 30 percent bed compression, when the flow rate was 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$). The maximum removal efficiency of the Fuzzy Filter occurs at different compression levels as the filtration rate is increased and the characteristics of the effluent to be filtered change. Maximum removal efficiency was observed to occur at 40 percent bed compression at a filtration rate of 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$), whereas 30 percent bed compression it was possible to produce the maximum

removal efficiency at filtration rates of 820 L/m^2•min (20 gal/ft^2•min), and 1230 L/m^2•min (30 gal/ft^2•min).

TURBIDITY REMOVAL EFFICIENCY

The evaluation of the Fuzzy Filter with respect to the removal of turbidity and the relationship between influent and effluent turbidity is considered in this section.

Removal Efficiency

Removal efficiency data are shown in Figs. A-1b through A-16b. The performance of the filter under different filtration conditions can be compared with each other easily after normalizing the turbidity data. It can be interpreted from the data plotted in Figs. A-1b through A-16b that removal efficiency is not effected significantly by the filtration rate, but is effected more by the compression level of the filter medium. Removal efficiency was maximized at 40 pecent bed compression when the flow rate was of 410 L/m^2•min (10 gal/ft^2•min) and at 30 percent bed compression for flow rates of both 820 L/m^2•min (20 gal/ft^2•min), and 1230 L/m^2•min (30 gal/ft^2•min). The reason for the maximum removal efficiency occurring at different compression levels when the flow rate is altered, is being investigated currently.

There is one disadvantage associated with reporting removal efficiency data as shown in shown in Figs. A-1b through A-16b. The reported removal efficiency will be lower when the influent turbidity is in the range from 1.5 to 3 NTU. At low influent turbidity values, the particle size distribution of the influent solids is shifted more towards the smaller colloidal sized particles than the typical particle size distribution observed when the influent turbidity is higher than 3 NTU. It should be noted that the turbidity of the secondary effluent from a typical activated sludge wastewater treatment plant is in the range from 3 to 8 NTU. The turbidity of the secondary effluent of the UCD wastewater treatment plant is often lower than 3 NTU for long periods of time (see Figs A-6a and A-11a). In these cases, the performance of the Fuzzy Filter should not be evaluated solely by the removal efficiency data. An important objective of this study is to determine the feasible ranges of compression level and the flow rate to obtain 2 NTU effluent turbidity.

Effluent Versus Influent Turbidity

To determine the influent turbidity value that can be filtered, without the use of chemicals, without exceeding the Title 22 turbidity requirements (2 NTU) an effluent versus influent turbidity analysis has been performed. The turbidity data from all the experimental filter runs have been aggregated in one turbidity unit increments. For example, all the filter effluent turbidities that correspond to influent turbidities of 3.5 to 4.499 NTU were read from the stored data for all the runs for a given filtration rate. The filter effluent turbidity readings are then averaged and reported at the average value of the filter influent turbidity (i.e., 4.0 NTU). The results of the effluent versus influent anlysis are plotted in Fig. 5-1 for the four filtration rates that were evaluated. As shown in Fig. 5-1, as the degree of bed compression increases, greater influent turbidity values can be handled at all of the filtration rates.

A general conclusion that can be reached is that the effluent turbidity will be equal to or lower than 2 NTU for influent turbidity values of up to approximately 8 NTU, when the flow rate is between 410 and 1230 $L/m^2 \cdot min$ (10 to 30 $gal/ft^2 \cdot min$) with a degree of bed compression of 30 percent. The performance of the Fuzzy Filter is consistent with the findings reported in Chap. 2 for the operation of conventional filters. It is important to note, however, that the Fuzzy Filter achieved the same performance levels at filtration rates varying from 6 to 15 as great as those used for the conventional filters.

HEAD LOSS DEVELOPMENT ACROSS THE FILTER MEDIUM

As noted previously, filtration rate, medium depth, collector size (usually defined as the average diameter of the medium grains), porosity, and the influent water quality are the principal parameters that effect effluent quality and development of head loss across the filter medium. The clean filter head loss, the development of head loss during filtration, and the development of head loss with the accumulation of solids are considered below.

Clean Filter Head Loss

The measured clean filter head loss across the filter medium as a function of the filtration rate and the degree of bed compression is shown in Fig. 5-2. As shown in Fig. 5-2, the initial head loss at flow rate of 205 $L/m^2 \cdot min$ (5 $gal/ft^2 \cdot min$) and 0 percent compression is 63 mm (2.5 in) of H_2O. This initial value increases linearly to a value of 127 mm (5 in) of H_2O at flow rate of 410 $L/m^2 \cdot min$

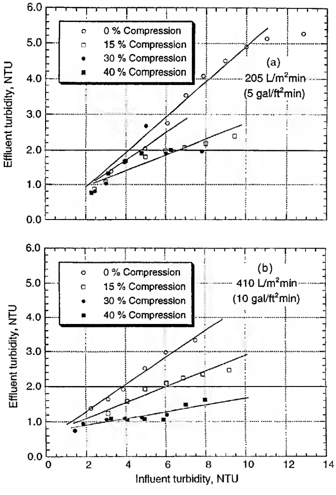

Figure 5-1
Effluent versus influent turbidity at various filtration rates: (a) 205 $L/m^2 \cdot min$ (5 $gal/ft^2 \cdot min$), (b) 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$), (c) 820 $L/m^2 \cdot min$ (20 $gal/ft^2 \cdot min$), (d) 1230 $L/m^2 \cdot min$ (30 $gal/ft^2 \cdot min$)

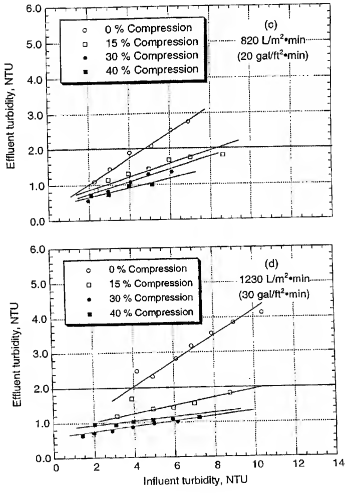

Figure 5-1 Continued

Effluent versus influent turbidity at various filtration rates: (a) 205 L/m^2•min (5 gal/ft^2•min), (b) 410 L/m^2•min (10 gal/ft^2•min), (c) 820 L/m^2•min (20 gal/ft^2•min), (d) 1230 L/m^2•min (30 gal/ft^2•min)

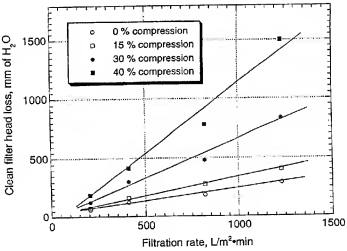

Figure 5-2
Initial clean bed head loss across the filter medium
versus filtration rate and bed compression

(10 gal/ft^2•min) and 0 percent compression. The fact that the head loss increases linearly is an indication that the flow regime through the filter is laminar. The impact of compression is clearly evident in the curves plotted in Fig. 5-2. It should also be noted that the increase in head loss at any given filtration rate is not a linear function of the degree of compression.

Effect Of Filtration Rate and Bed Compression On Headloss

As mentioned above, increasing the degree of bed compression increases both the removal efficiency and the head loss occurring across the filter medium. There exists a compression level which assure the desired effluent quality, while keeping the head loss occurring across the filter medium in reasonable levels. The development of headloss with time for the different filtration rates and bed compression values is illustrated in Figs. A-1c through A-16c in Appendix A. As shown in these figures, depending on the filtration rate, there is gradual buildup of headloss with time as suspended solids accumulate within the filter. As some critical point is reached, the headloss starts to increase curvalinearly, which characteristic of removal by straining.

Head Loss Versus Suspended Solids Accumulation

The development of the head loss across the filter medium is related to the suspended solids accumulation in the medium. Suspended solids accumulation in the filter medium was calculated by using the influent/effluent turbidities versus time data, and the following relation:

$$\text{Suspended solids (g/L)} = 0.0023 \times \text{Turbidity (NTU)} \qquad (5\text{-}1)$$

The suspended solids accumulation in the medium at any time is calculated by the following mass balance equation:

$$SS_{acc} = 0.0023\,\Delta t\,\frac{Q}{V}\sum_{i=1}^{i=t/\Delta t}\left(Turb_{inf} - Turb_{eff}\right)_i \qquad (5\text{-}2)$$

where SS_{acc} = suspended solids accumulation at time t, g/m^3

Q = filtration rate, L/min

V = volume of filter medium, m^3

Δt = data collection frequency, min

$Turb_{inf}$ = influent turbidity, NTU

$Turb_{eff}$ = effluent turbidity, NTU
i = time index of the collected data

The correlation coefficient of 0.0023, developed during the earlier studies performed at the UCD wastewater treatment plant, was verified in this study. The development of headloss with time is shown in Figs. 5-3b and 5-4b. The corresponding development of head loss based on the amount of suspended solids retained within the filter is shown Figs. 5-3c and 5-4c. The relationship between the accumulation of solids and the development of head loss is currently under investigation.

OVERALL FILTER PERFORMANCE

In addition to the evaluation of the Fuzzy Filter with respect to the removal of turbidity and the development of headloss, other important considerations include the quantity of backwash water used relative to the amount of water processed. Summary data on the operation of the Fuzzy Filter including backwash water use and water production are presented in Table 5-1.

Backwash Water Requirements

Secondary effluent is used as the backwash water. A backwash rate of 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$) was observed to be sufficient for the cleanup of the medium. The cleanup operation of the filter medium takes approximately 30 minutes. The reduction of 30 minutes of backwash cycle time to approximately 20 minutes is currently under investigation. The percentage of the total water utilized for backwashing the Fuzzy Filter, as summarized in Column 5 of Table 5-1, was computed using the following expression.

$$\text{Backwash water, \%} = \frac{W_B}{W_F + W_B} \times 100 \qquad (5\text{-}3)$$

Where W_B = water used for backwashing the filter
W_F = total filtered water

Based on preliminary testing results, it appears that it may be possible to reduce the amount of backwash water to about one percent. The ability to reduce the amount of backwash water has significant cost implications with respect to the sizing of the wastewater treatment processes. By comparison, the typical

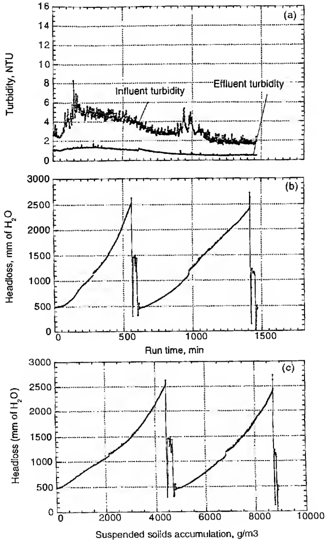

Figure 5-3
Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) headloss development versus time, and (c) headloss development versus suspended solids accumulation

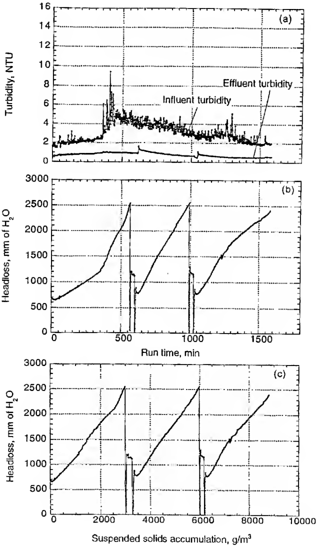

Figure 5-4
Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) headloss development versus time, and (c) headloss development versus suspended solids accumulation

Table 5-1
Summary performance data for Fuzzy Filter

Run no.	Filtration rate		Comp. ratio, %	Back wash water, %	Total water produced	
	L/m²•min	gal/ft²•min			L/m²•d	gal/ft²•d
1	205	5	0	4.1	289,000	7,083
2	205	5	15	4.1	289,000	7,083
3	205	5	30	4.1	289,000	7,083
4	205	5	40	4.1	289,000	7,083
5	410	10	0	2.1	578,000	14,170
6	410	10	15	2.1	578,000	14,170
7	410	10	30	2.1	578,000	14,170
8	410	10	40	3.1	572,000	14,020
9	820	20	0	1.1	1,156,200	28,340
10	820	20	15	1.7	1,139,800	27,940
11	820	20	30	2.0	1,131,600	27,735
12	820	20	40	2.8	1,115,200	27,333
13	1,230	30	0	1.8	1,685,100	41,300
14	1,230	30	15	1.8	1,672,800	41,000
15	1,230	30	30	3.1	1,629,750	39,950
16	1,230	30	40	5.4	1,500,600	36,780

backwash percentage for most conventional effluent filters is from 6 to 15 percent.

Total Water Production

An important feature of any filtration system is the amount of water produced during a given time interval. In the filtration studies described in this report, the time interval is one day. Taking into account the water used for backwashing, the water production rate for various filtration rates and bed compression ratios is reported in the last two columns of Table 5-1. As shown, it was possible to produce 1,685,100 L/m²•d (41,300 gal/ft²•d), at a filtration rate of 1,230 L/m²•min (30 gal/ft²•min) and bed compression of 15 percent.

COMPARISON WITH OTHER FILTER TECHNOLOGIES

As illustrated in Fig. 5.1c and 5.1d, effluent turbidity values using the Fuzzy Filter, without chemical addition, will be equal to or lower than 2 NTU for influent turbitidy values of up to approximately 8 NTU, when the flow rate is between 820 and 1,230 L/m^2•min (20 and 30 gal/ft^2•min) at bed compression ratios between 15 and 40 percent. The perfomance of the Fuzzy Filter with respect to the removal of turbidity is similar to the perfomance of other filters (see Fig. 5-5) with one major exception: the filtration rate is more than 5 to 6 times the filtration rate of the other filters.

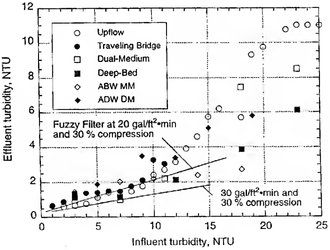

Figure 5-5
Comparison of effluent versus influent turbidity for Fuzzy Filter at 20 and 30 gal/ft^2•min and 30 percent compression and various filters operated at 5 gal/ft^2•min

6
CONCLUSIONS

The principal conclusions resulting from the evaluation of the Fuzzy Filter for the filtration of activated sludge effluent are as follows:

1. The Fuzzy Filter is effective for the filtration of effluent from an activated sludge treatment process.
2. The ability to compress the filter medium is a significant factor in the operation of the Fuzzy Filter, as the porosity of the bed can be modified to meet the characteristics of the liquid being filtered.
3. Because of the high porosity of the filter bed, significantly higher filtration rates [820 to 1,230 $L/m^2 \cdot min$ (20 to 30 $gal/ft^2 \cdot min$)] can be used effectively as compared to conventional granular medium filters [80 to 410 $L/m^2 \cdot min$ (2 to 10 $gal/ft^2 \cdot min$)].
4. Based on the observed removal efficiency and overall water production rate, the optimum filtration rate appears to be in the range from 820 to 1,230 $L/m^2 \cdot min$ (20 to 30 $gal/ft^2 \cdot min$) at bed compression values between 15 and 30 percent.
5. Effluent turbidity values, without chemical addition, will be equal to or lower than 2 NTU for influent turbitidy values of up to approximately 8 NTU, when the flow rate is between 820 and 1,230 $L/m^2 \cdot min$ (20 and 30 $gal/ft^2 \cdot min$) at bed compression ratios between 15 and 40 percent.
6. Secondary effluent is used as the backwash water. A flow rate of 410 $L/m^2 \cdot min$ (10 $gal/ft^2 \cdot min$) was observed to be sufficient to clean the filter medium.
7. The percentage of backwash water required at filtration rates of 820 and 1,230 $L/m^2 \cdot min$ (20 to 30 $gal/ft^2 \cdot min$) and bed compression values between 20 and 30 percent varied from 3.1 to 1.1 percent.
8. It was possible to produce 1,685,100 $L/m^2 \cdot d$ (41,300 $gal/ft^2 \cdot d$), at a filtration rate of 1,230 $L/m^2 \cdot min$ (30 $gal/ft^2 \cdot min$) and a bed compression of 15 percent.

REFERENCES

CSDLAC (1977) "Pomona Virus Study," County Sanitation Districts of Los Angeles County, Whittier, CA.

Lang, R., B. Weinschrott, and G. Tchobanoglous (1986) "Evaluation of the Aqua-Aerobics Automatic Backwash Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

Matsumoto, M. R., and G. Tchobanoglous (1981) "Evaluation of the Pulsed-Bed Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

Montgomery, J. M., Consulting Engineers, Inc. (1979) "Pilot Filtration Studies at the Tapia Water Reclamation Facility," Pasadena, CA.

Standard Methods for the Examination of Water and Wastewater (1992) 18th ed., American Public Health Association.

Tchobanoglous, G., and R. Eliassen (1970) "Filtration of Treated Sewage Effluent," Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 96, pp. 243-265.

Weinschrott, B., and G. Tchobanoglous (1986) "Evaluation of the Parkson DynaSand® Filter for Wastewater Reclamation in California," Department of Civil Engineering, University of California at Davis, Davis, CA.

APPENDIX A
FILTER RUN DATA

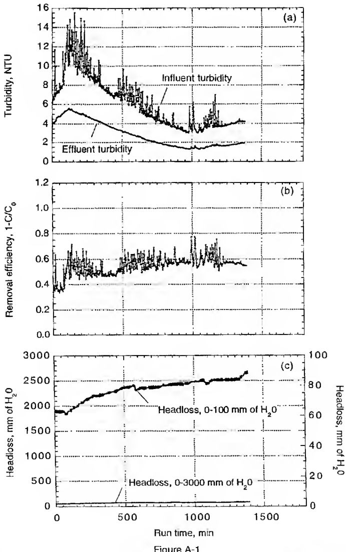

Figure A-1

Filtration of activated sludge effluent at a filtration rate of 205 L/m²•min (5 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

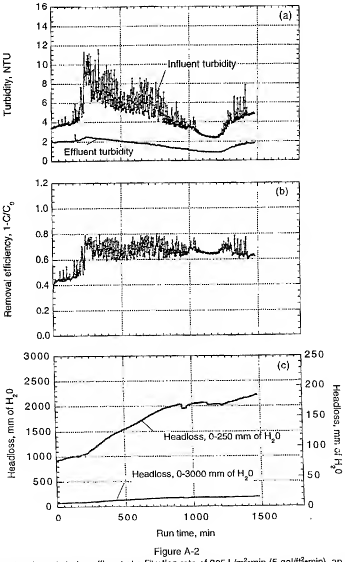

Figure A-2
Filtration of activated sludge effluent at a filtration rate of 205 L/m^2•min (5 gal/ft^2•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

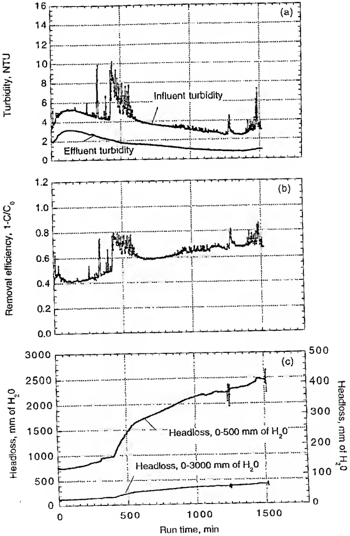

Figure A-3
Filtration of activated sludge effluent at a filtration rate of 205 L/m²•min (5 gal/ft²•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

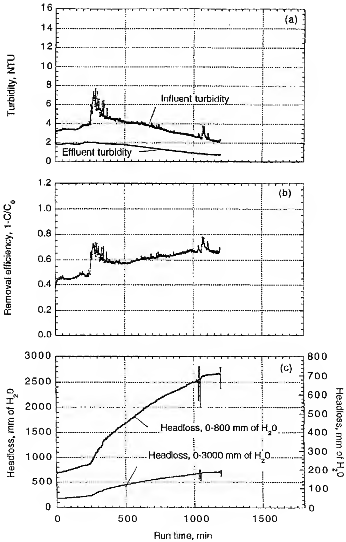

Figure A-4
Filtration of activated sludge effluent at a filtration rate of 205 L/m²•min (5 gal/ft²•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

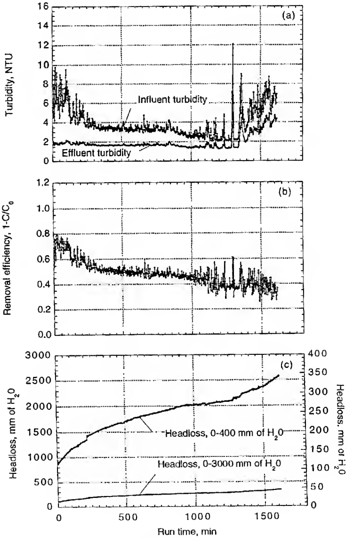

Figure A-5
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

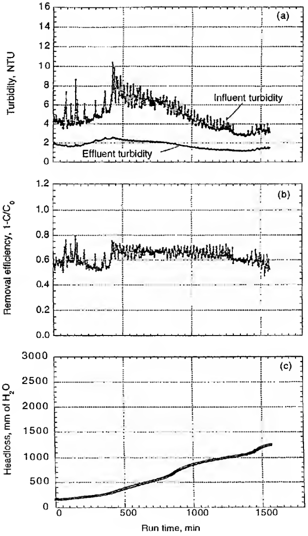

Figure A-6
Filtration of activated sludge effluent at a filtration rate of 410 L/m^2•min (10 gal/ft^2•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

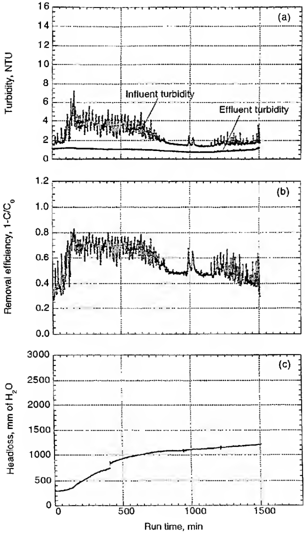

Figure A-7
Filtration of activated sludge effluent at a filtration rate of 410 L/m²•min (10 gal/ft²•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

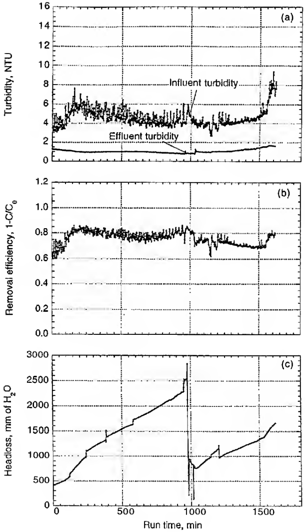

Figure A-8
Filtration of activated sludge effluent at a filtration rate of 410 L/m^2•min (10 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

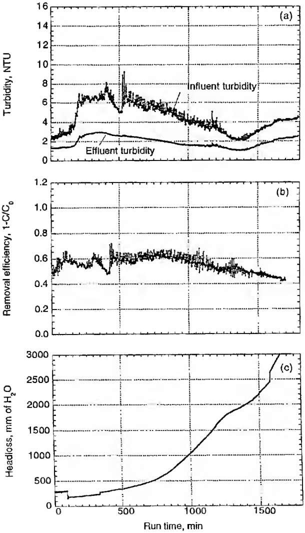

Figure A-9

Filtration of activated sludge effluent at a filtration rate of 820 L/m²•min (20 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

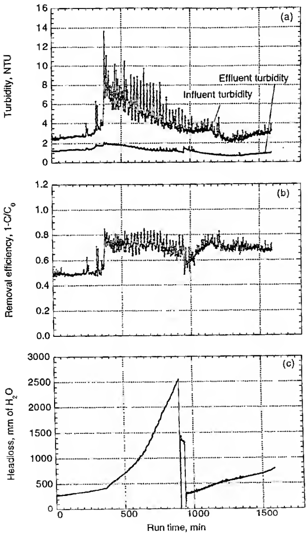

Figure A-10
Filtration of activated sludge effluent at a filtration rate of 820 L/m²•min (20 gal/ft²•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

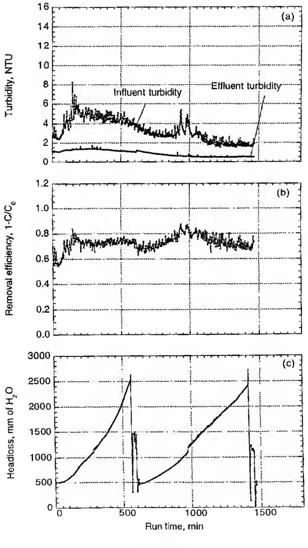

Figure A-11

Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

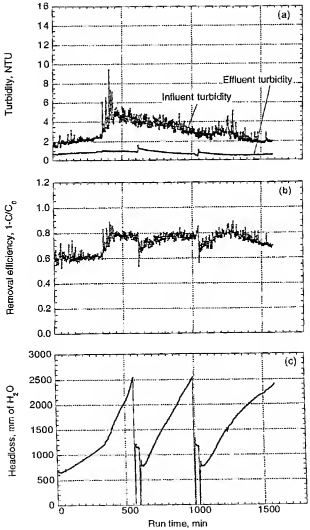

Figure A-12

Filtration of activated sludge effluent at a filtration rate of 820 L/m^2•min (20 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

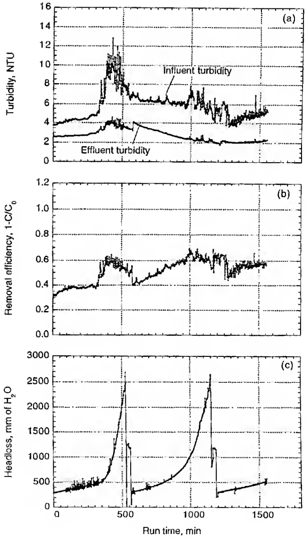

Figure A-13
Filtration of activated sludge effluent at a filtration rate of 1230 L/m²•min (30 gal/ft²•min), an initial bed depth of 30 in, and 0 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

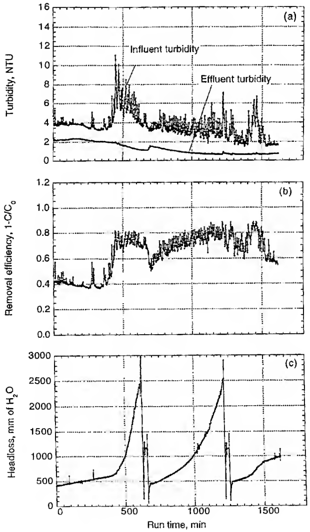

Figure A-14
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 15 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

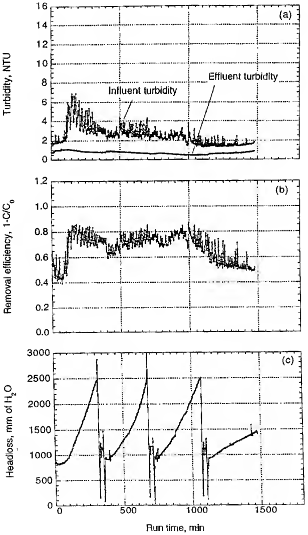

Figure A-15
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 30 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

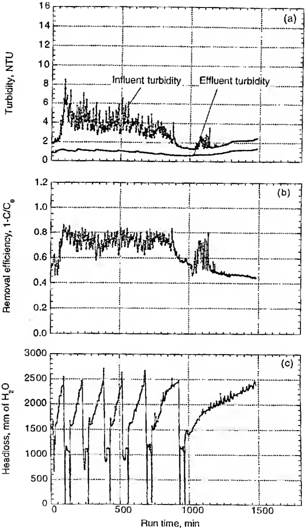

Figure A-16
Filtration of activated sludge effluent at a filtration rate of 1230 L/m^2•min (30 gal/ft^2•min), an initial bed depth of 30 in, and 40 percent compression: (a) influent and effluent turbidity data versus time, (b) turbidity removal efficiency versus time, and (c) headloss development versus time

WHAT IS CLAIMED IS:

1. High rate wastewater filtration apparatus comprising:

an inlet for introducing wastewater into said apparatus for upward flow through said apparatus;

an outlet for discharging filtered water from said apparatus;

a first perforated panel immovably mounted within said apparatus;

a second perforated panel movably mounted within said apparatus and spaced above said first perforated panel;

means for selectively moving said movably mounted second perforated panel toward and away from said first perforated panel, said means being located above said first and second perforated panels;

a compressible media disposed between said first and second perforated panels, said compressible media being compressed in a gradient proceeding from more compressed to less compressed in a direction opposite to the flow of wastewater so that filtration proceeds in a direction from a more porous to a less porous filter; and

means for washing said filter media when said filter media becomes clogged.

2. A process for tertiary wastewater treatment comprising the steps of:

a) treating wastewater in an activated sludge reactor to provide a treated reactor effluent;

b) treating the reactor effluent in a clarifier to provide a clarifier effluent;

c) providing at least a portion of the clarifier effluent to the high rate wastewater filtration apparatus of Claim 1 and filtering the

clarifier effluent to provide a tertiary treatment of the wastewater.

BAR CODE LABEL	U.S. PATENT APPLICATION		
SERIAL NUMBER 60/032,643 PROVISIONAL	FILING DATE 12/10/96	CLASS	GROUP ART UNIT

APPLICANT

WILLIAM F. DEW JR., HOMEWOOD, AL.

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STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS	FILING FEE RECEIVED	ATTORNEY DOCKET NO.
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TOTAL CLAIMS	INDEPENDENT CLAIMS	SMALL ENTITY?	FILING FEE	FOREIGN LICENSE	ATTORNEY DOCKET NUMBER
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INVENTOR(s)/APPLICANT(s)

Name: William Frederick Dew, Jr.
Address: 841 Sylvia Drive
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TITLE OF THE INVENTION *(280 characters maximum)*

HIGH RATE FILTRATION SYSTEM

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ENCLOSED APPLICATION PARTS *(check all that apply)*

X Specification (Number of Pages 56)

__ Drawing(s) (Number of Sheets __)

X Claims (Number of Claims 2)
(A complete provisional application does not require claims 37 C.F.R. § 1.51(a)(2).)

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[signature] June 26, 2007
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